Fedora 17

System Administrator's Guide

Deployment, Configuration, and Administration of Fedora 17



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The *System Administrator's Guide* documents relevant information regarding the deployment, configuration, and administration of Fedora 17. It is oriented towards system administrators with a basic understanding of the system.

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Preface

The *System Administrator's Guide* contains information on how to customize the Fedora 17 system to fit your needs. If you are looking for a comprehensive, task-oriented guide for configuring and customizing your system, this is the manual for you.

This manual discusses many intermediate topics such as the following:

- Installing and managing packages using the graphical **PackageKit** and command line **Yum** package managers
- Setting up a network—from establishing an Ethernet connection using **NetworkManager** to configuring channel bonding interfaces to increase server bandwidth
- Configuring `DHCP`, **BIND**, **Apache HTTP Server**, **Postfix**, **Sendmail** and other enterprise-class servers and software
- Gathering information about your system, including obtaining user-space crash data with the **Automatic Bug Reporting Tool**, and kernel-space crash data with `kdump`
- Easily working with kernel modules and upgrading the kernel

1. Target Audience

The *Deployment Guide* assumes you have a basic understanding of the Fedora operating system. If you need help with the installation of this system, refer to the *Fedora 17 Installation Guide*[1].

2. How to Read this Book

This manual is divided into the following main categories:

Part I, "Basic System Configuration"

This part covers basic system administration tasks such as keyboard configuration, date and time configuration, and managing users and groups.

Chapter 1, Configuring the Language and Keyboard covers basic language and keyboard setup. Read this chapter if you need to configure the language of your desktop, change the keyboard layout, or add the keyboard layout indicator to the panel.

Chapter 2, Configuring the Date and Time covers the configuration of the system date and time. Read this chapter if you need to change the date and time setup, or configure the system to synchronize the clock with a remote Network Time Protocol (NTP) server.

Chapter 3, Managing Users and Groups covers the management of users and groups in a graphical user interface and on the command line. Read this chapter if you need to manage users and groups on your system, or enable password aging.

Part II, "Package Management"

This part describes how to manage software packages on Fedora using both **Yum** and the **PackageKit** suite of graphical package management tools.

Chapter 4, Yum describes the **Yum** package manager. Read this chapter for information how to search, install, update, and uninstall packages on the command line.

[1] http://docs.fedoraproject.org/en-US/Fedora/16/html/Installation_Guide/index.html

Chapter 5, PackageKit describes the **PackageKit** suite of graphical package management tools. Read this chapter for information how to search, install, update, and uninstall packages using a graphical user interface.

Part III, "Networking"

This part describes how to configure the network on Fedora.

Chapter 7, Network Interfaces explores various interface configuration files, interface control scripts, and network function files located in the **`/etc/sysconfig/network-scripts/`** directory. Read this chapter for information how to use these files to configure network interfaces.

Part IV, "Infrastructure Services"

This part provides information how to configure services and daemons, configure authentication, and enable remote logins.

Chapter 8, Services and Daemons covers the configuration of the services to be run when a system is started, and provides information on how to start, stop, and restart the services on the command line using the **`systemctl`** utility.

Chapter 9, Configuring Authentication describes how to configure user information retrieval from Lightweight Directory Access Protocol (LDAP), Network Information Service (NIS), and Winbind user account databases, and provides an introduction to the System Security Services Daemon (SSSD). Read this chapter if you need to configure authentication on your system.

Chapter 10, OpenSSH describes how to enable a remote login via the SSH protocol. It covers the configuration of the `sshd` service, as well as a basic usage of the **`ssh`**, **`scp`**, **`sftp`** client utilities. Read this chapter if you need a remote access to a machine.

Part V, "Servers"

This part discusses various topics related to servers such as how to set up a Web server or share files and directories over the network.

Chapter 11, DHCP Servers guides you through the installation of a Dynamic Host Configuration Protocol (DHCP) server and client. Read this chapter if you need to configure DHCP on your system.

Chapter 12, DNS Servers introduces you to Domain Name System (DNS), explains how to install, configure, run, and administer the **BIND** DNS server. Read this chapter if you need to configure a DNS server on your system.

Chapter 13, Web Servers focuses on the **Apache HTTP Server 2.2**, a robust, full-featured open source web server developed by the Apache Software Foundation. Read this chapter if you need to configure a web server on your system.

Chapter 14, Mail Servers reviews modern email protocols in use today, and some of the programs designed to send and receive email, including **Postfix**, **Sendmail**, **Fetchmail**, and **Procmail**. Read this chapter if you need to configure a mail server on your system.

Chapter 15, Directory Servers covers the installation and configuration of **OpenLDAP 2.4**, an open source implementation of the LDAPv2 and LDAPv3 protocols. Read this chapter if you need to configure a directory server on your system.

Chapter 16, File and Print Servers guides you through the installation and configuration of **Samba**, an open source implementation of the Server Message Block (SMB) protocol, and **vsftpd**, the primary FTP server shipped with Fedora. Additionally, it explains how to use the **Printer Configuration** tool to configure printers. Read this chapter if you need to configure a file or print server on your system.

Part VI, "Monitoring and Automation"

This part describes various tools that allow system administrators to monitor system performance, automate system tasks, and report bugs.

Chapter 17, System Monitoring Tools discusses applications and commands that can be used to retrieve important information about the system. Read this chapter to learn how to gather essential system information.

Chapter 18, Viewing and Managing Log Files describes the configuration of the `rsyslog` daemon, and explains how to locate, view, and monitor log files. Read this chapter to learn how to work with log files.

Chapter 19, Automating System Tasks provides an overview of the **`cron`**, **`at`**, and **`batch`** utilities. Read this chapter to learn how to use these utilities to perform automated tasks.

Chapter 20, OProfile covers **OProfile**, a low overhead, system-wide performance monitoring tool. Read this chapter for information how to use **OProfile** on your system.

Part VII, "Kernel, Module and Driver Configuration"

This part covers various tools that assist administrators with kernel customization.

Chapter 21, Manually Upgrading the Kernel provides important information how to manually update a kernel package using the **`rpm`** command instead of **`yum`**. Read this chapter if you cannot update a kernel package with the **`Yum`** package manager.

Chapter 22, Working with Kernel Modules explains how to display, query, load, and unload kernel modules and their dependencies, and how to set module parameters. Additionally, it covers specific kernel module capabilities such as using multiple Ethernet cards and using channel bonding. Read this chapter if you need to work with kernel modules.

Chapter 23, The kdump Crash Recovery Service explains how to configure, test, and use the `kdump` service in Fedora, and provides a brief overview of how to analyze the resulting core dump using the **crash** debugging utility. Read this chapter to learn how to enable `kdump` on your system.

Appendix A, Consistent Network Device Naming

This appendix covers consistent network device naming for network interfaces, a feature that changes the name of network interfaces on a system in order to make locating and differentiating the interfaces easier. Read this appendix to learn more about this feature and how to enable or disable it.

Appendix B, RPM

This appendix concentrates on the RPM Package Manager (RPM), an open packaging system used by Fedora, and the use of the **`rpm`** utility. Read this appendix if you need to use **`rpm`** instead of **`yum`**.

Appendix C, The X Window System

This appendix covers the configuration of the X Window System, the graphical environment used by Fedora. Read this appendix if you need to adjust the configuration of your X Window System.

Appendix D, The sysconfig Directory

This appendix outlines some of the files and directories located in the **`/etc/sysconfig/`** directory. Read this appendix if you want to learn more about these files and directories, their function, and their contents.

Appendix E, The proc File System
: This appendix explains the concept of a virtual file system, and describes some of the top-level files and directories within the `proc` file system (that is, the **`/proc/`** directory). Read this appendix if you want to learn more about this file system.

3. Document Conventions

This manual uses several conventions to highlight certain words and phrases and draw attention to specific pieces of information.

In PDF and paper editions, this manual uses typefaces drawn from the *Liberation Fonts*[2] set. The Liberation Fonts set is also used in HTML editions if the set is installed on your system. If not, alternative but equivalent typefaces are displayed. Note: Red Hat Enterprise Linux 5 and later includes the Liberation Fonts set by default.

3.1. Typographic Conventions

Four typographic conventions are used to call attention to specific words and phrases. These conventions, and the circumstances they apply to, are as follows.

`Mono-spaced Bold`

Used to highlight system input, including shell commands, file names and paths. Also used to highlight keycaps and key combinations. For example:

> To see the contents of the file **`my_next_bestselling_novel`** in your current working directory, enter the **`cat my_next_bestselling_novel`** command at the shell prompt and press **`Enter`** to execute the command.

The above includes a file name, a shell command and a keycap, all presented in mono-spaced bold and all distinguishable thanks to context.

Key combinations can be distinguished from keycaps by the hyphen connecting each part of a key combination. For example:

> Press **`Enter`** to execute the command.
>
> Press **`Ctrl`**+**`Alt`**+**`F2`** to switch to the first virtual terminal. Press **`Ctrl`**+**`Alt`**+**`F1`** to return to your X-Windows session.

The first paragraph highlights the particular keycap to press. The second highlights two key combinations (each a set of three keycaps with each set pressed simultaneously).

If source code is discussed, class names, methods, functions, variable names and returned values mentioned within a paragraph will be presented as above, in **`mono-spaced bold`**. For example:

> File-related classes include **`filesystem`** for file systems, **`file`** for files, and **`dir`** for directories. Each class has its own associated set of permissions.

Proportional Bold

This denotes words or phrases encountered on a system, including application names; dialog box text; labeled buttons; check-box and radio button labels; menu titles and sub-menu titles. For example:

[2] https://fedorahosted.org/liberation-fonts/

> Choose **System□□□ Preferences□□□ Mouse** from the main menu bar to launch **Mouse Preferences**. In the **Buttons** tab, click the **Left-handed mouse** check box and click **Close** to switch the primary mouse button from the left to the right (making the mouse suitable for use in the left hand).
>
> To insert a special character into a **gedit** file, choose **Applications□□□ Accessories □□ Character Map** from the main menu bar. Next, choose **Search□□□ Find…** from the **Character Map** menu bar, type the name of the character in the **Search** field and click **Next**. The character you sought will be highlighted in the **Character Table**. Double-click this highlighted character to place it in the **Text to copy** field and then click the **Copy** button. Now switch back to your document and choose **Edit□□ Paste** from the **gedit** menu bar.

The above text includes application names; system-wide menu names and items; application-specific menu names; and buttons and text found within a GUI interface, all presented in proportional bold and all distinguishable by context.

Mono-spaced Bold Italic or ***Proportional Bold Italic***

Whether mono-spaced bold or proportional bold, the addition of italics indicates replaceable or variable text. Italics denotes text you do not input literally or displayed text that changes depending on circumstance. For example:

> To connect to a remote machine using ssh, type **ssh *username*@*domain.name*** at a shell prompt. If the remote machine is **example.com** and your username on that machine is john, type **ssh john@example.com**.
>
> The **mount -o remount *file-system*** command remounts the named file system. For example, to remount the **/home** file system, the command is **mount -o remount /home**.
>
> To see the version of a currently installed package, use the **rpm -q *package*** command. It will return a result as follows: ***package-version-release***.

Note the words in bold italics above — username, domain.name, file-system, package, version and release. Each word is a placeholder, either for text you enter when issuing a command or for text displayed by the system.

Aside from standard usage for presenting the title of a work, italics denotes the first use of a new and important term. For example:

> Publican is a *DocBook* publishing system.

3.2. Pull-quote Conventions

Terminal output and source code listings are set off visually from the surrounding text.

Output sent to a terminal is set in **mono-spaced roman** and presented thus:

```
books        Desktop   documentation  drafts  mss    photos   stuff  svn
books_tests  Desktop1  downloads      images  notes  scripts  svgs
```

Source-code listings are also set in **mono-spaced roman** but add syntax highlighting as follows:

```
package org.jboss.book.jca.ex1;
```

```
import javax.naming.InitialContext;

public class ExClient
{
   public static void main(String args[])
       throws Exception
   {
      InitialContext iniCtx = new InitialContext();
      Object         ref    = iniCtx.lookup("EchoBean");
      EchoHome       home   = (EchoHome) ref;
      Echo           echo   = home.create();

      System.out.println("Created Echo");

      System.out.println("Echo.echo('Hello') = " + echo.echo("Hello"));
   }
}
```

3.3. Notes and Warnings

Finally, we use three visual styles to draw attention to information that might otherwise be overlooked.



Note

Notes are tips, shortcuts or alternative approaches to the task at hand. Ignoring a note should have no negative consequences, but you might miss out on a trick that makes your life easier.



Important

Important boxes detail things that are easily missed: configuration changes that only apply to the current session, or services that need restarting before an update will apply. Ignoring a box labeled 'Important' will not cause data loss but may cause irritation and frustration.



Warning

Warnings should not be ignored. Ignoring warnings will most likely cause data loss.

4. We Need Feedback!

If you find a typographical error in this manual, or if you have thought of a way to make this manual better, we would love to hear from you! Please submit a report in Bugzilla: *https://bugzilla.redhat.com/enter_bug.cgi?product=Fedora Documentation&component=system-administrator's-guide*

If you have a suggestion for improving the documentation, try to be as specific as possible when describing it. If you have found an error, please include the section number and some of the surrounding text so we can find it easily.

5. Acknowledgments

Certain portions of this text first appeared in the *Deployment Guide*, copyright © 2007 Red Hat, Inc., available at *http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/5/html/Deployment_Guide/index.html*.

Section 17.6, "Monitoring Performance with Net-SNMP" is based on an article written by Michael Solberg.

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Part I. Basic System Configuration

This part covers basic system administration tasks such as keyboard configuration, date and time configuration, and managing users and groups.

Configuring the Language and Keyboard

Fedora 17 is shipped with the **Region and Language** configuration tool, which allows you to configure keyboard layouts, the language of your desktop environment, and other regional settings. To start the tool, open the **System Settings** window by selecting **Applications** **System Tools** **System Settings** from the **Activities** menu, and click **Region and Language**.

1.1. Changing the Language

To configure the language of your desktop, select the **Language** tab of the **Region and Language** application. You will be presented with a short list of common languages.

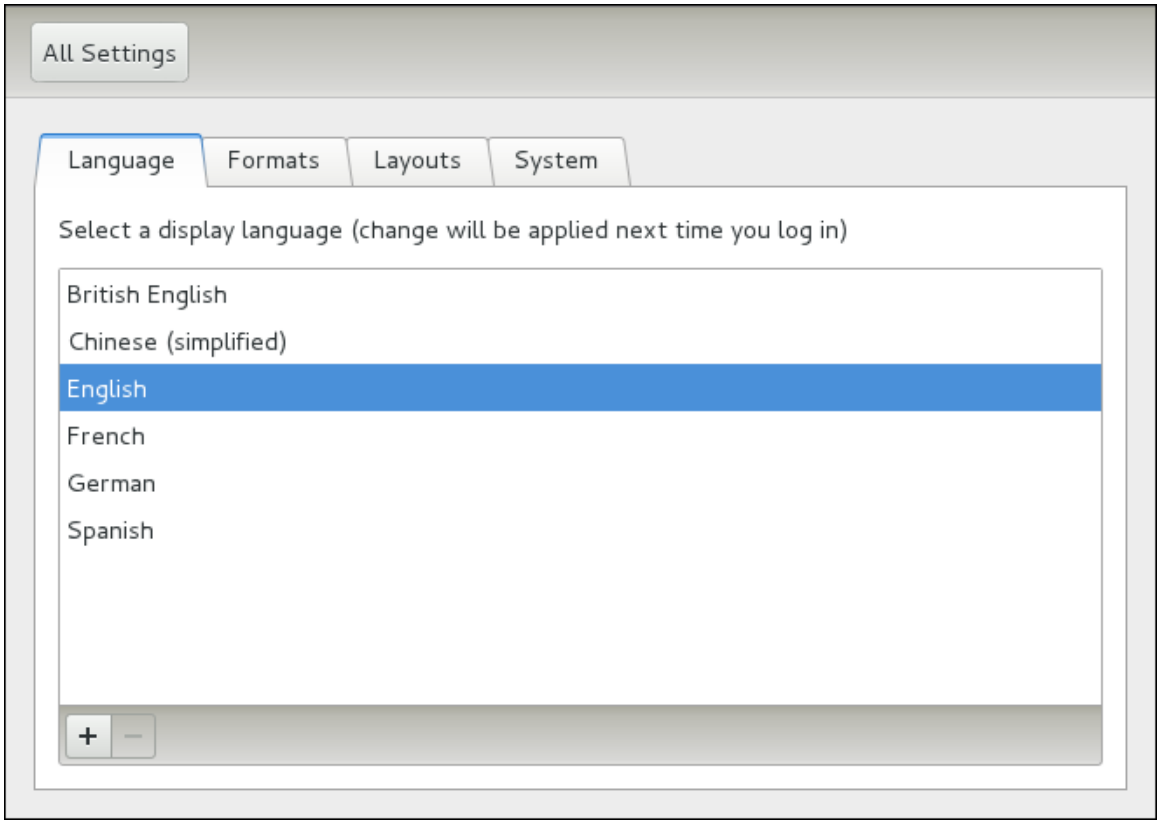


Figure 1.1. Changing the language

By default, this list only contains a few of the available languages. To add another language, click the **+** (the plus sign) button below the list. A dialog window appears, allowing you to select the desired language. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by first few letters part of the language name in it (for example, “slov” for the Slovak language). Once you select a language, click the **Select** button to confirm your choice.

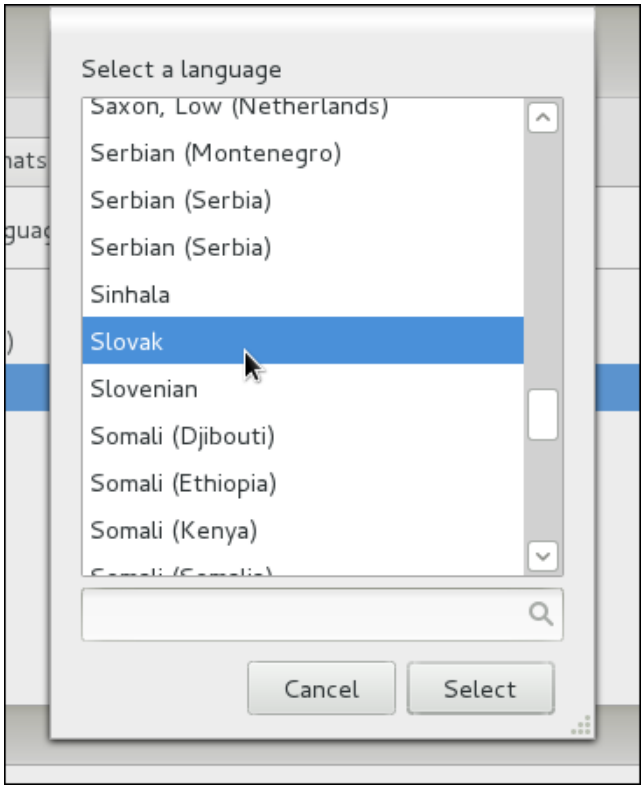


Figure 1.2. Adding another language

To choose a particular language from the list, click its name to select it. The changes will take effect the next time you log in to the system.

1.2. Changing the Date, Time, and Numeric Format

To change the default date, time, number, and currency format, select the **Formats** tab of the **Region and Language** application. You will be presented with a short list of available formats.

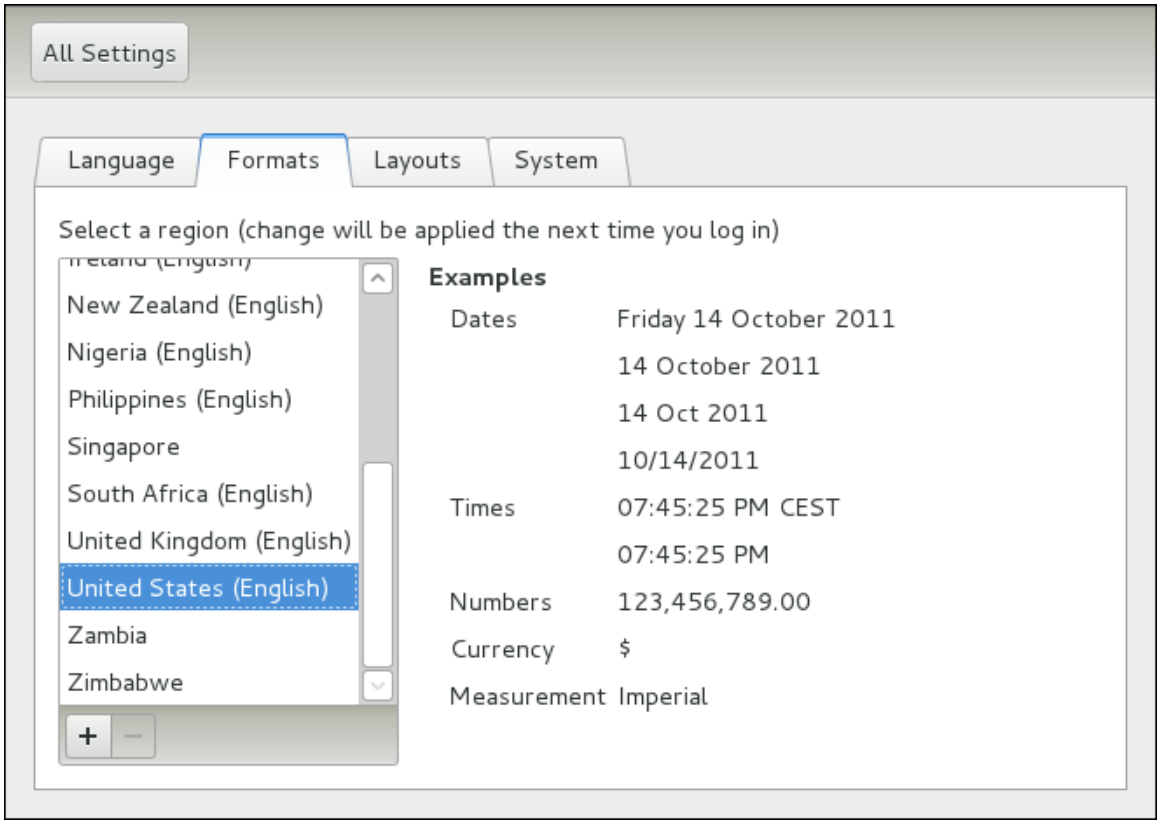


Figure 1.3. Changing the date, time, and numeric format

By default, this list only contains a few of the available formats. To add another format, click the **+** (the plus sign) button below the list. A dialog window appears, allowing you to select the desired format according to a region. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by typing first few letters of the region name in it (for example, “slov” for Slovakia). Once you select a region, click the **Select** button to confirm your choice.

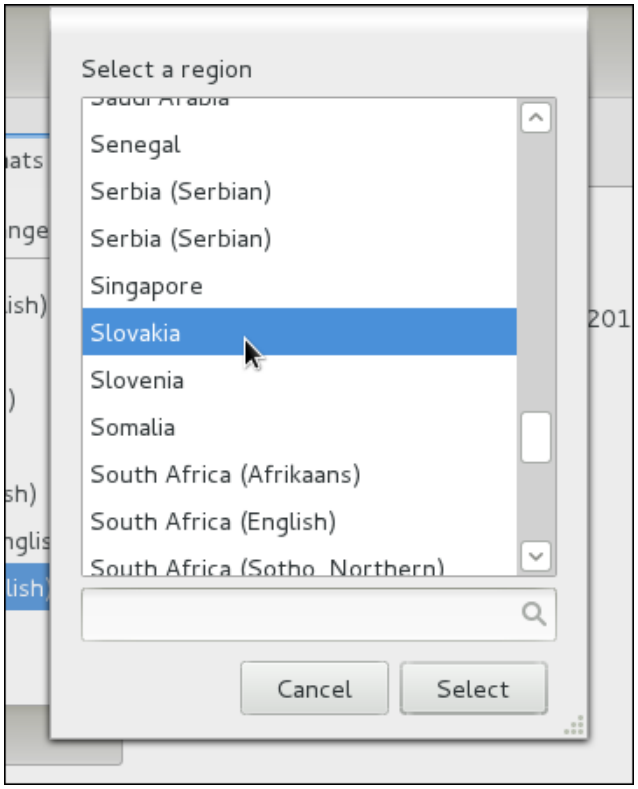


Figure 1.4. Adding a format

To choose a particular format from the list, click its name to select it. The changes will take effect the next time you log in to the system.

1.3. Changing the Keyboard Layout

Although the installation program allows a system administrator to configure a keyboard layout during the system installation, the default settings may not always suit your current needs. To change the default keyboard layout, select the **Layouts** tab of the **Region and Language** application. You will be presented with a list of currently enabled layouts.

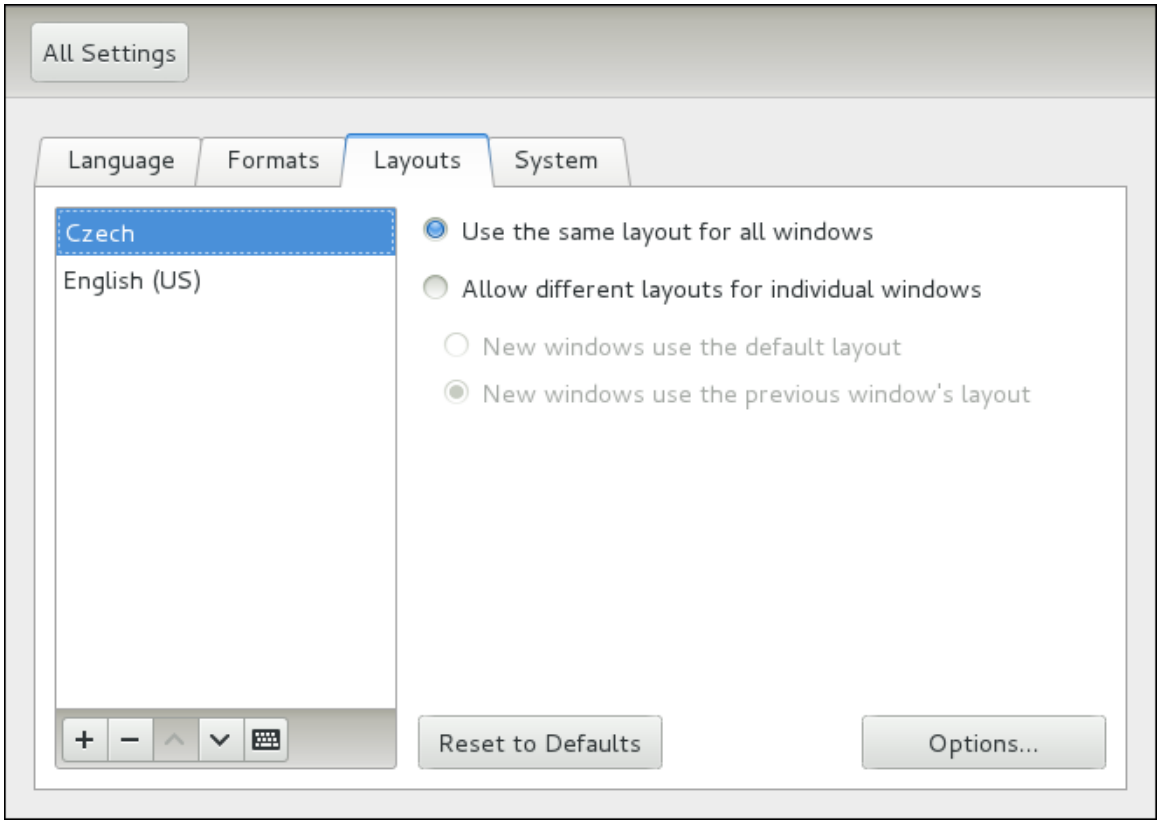


Figure 1.5. Changing the keyboard layout

To add a layout to the list, click the **+** (the plus sign) button below the list. A dialog window appears, allowing you to select the desired keyboard layout. The input field at the bottom part of the dialog window allows you to reduce the number of displayed items by typing first few letters of the layout name in it (for example, “slov” for a Slovak layout). Once you select a layout, click the **Add** button to confirm your choice.

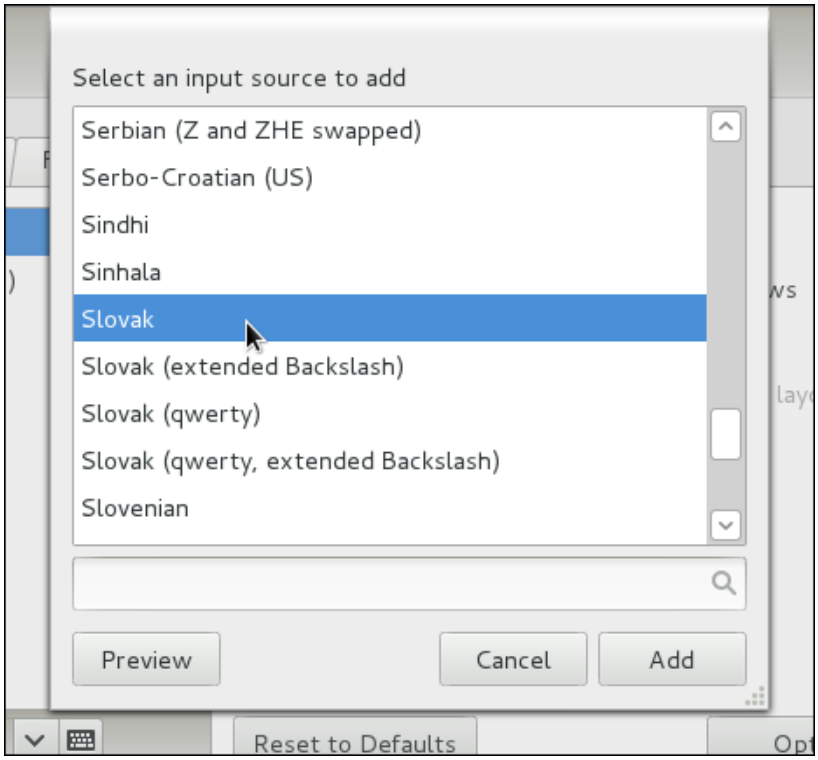


Figure 1.6. Adding a keyboard layout

The first layout in the list is always considered the default. To move a particular layout up or down in the list, select it and click the # (the upwards arrow) or # (the downwards arrow) buttons respectively. To remove a layout, click the − (that is, the minus sign) button. Additionally, by selecting an option button on the right side of the window, you can choose if you want to use different keyboard layouts for individual windows, or a single layout for all windows.

When more than one layout is enabled, a keyboard indicator appears on the panel in order to allow you to switch between the layouts.

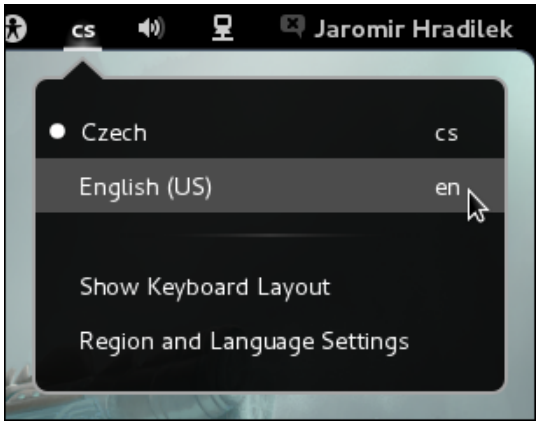


Figure 1.7. The keyboard layout indicator

1.4. Viewing the Current Configuration

To view the current configuration, select the **System** tab of the **Region and Language** application. You will be presented with a comparison of your own configuration and system-wide settings.

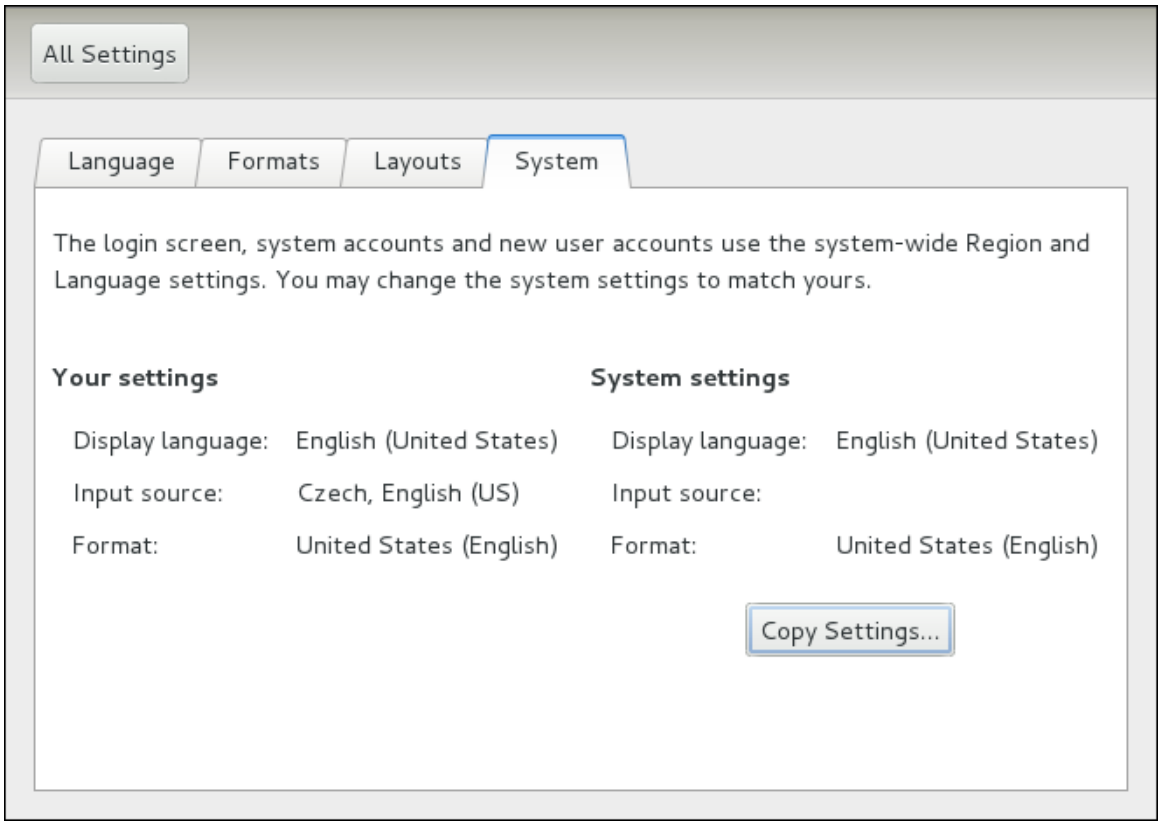


Figure 1.8. Viewing the current configuration

Configuring the Date and Time

This chapter covers setting the system date and time in Fedora, both manually and using the Network Time Protocol (NTP), as well as setting the adequate time zone. Two methods are covered: setting the date and time using the **Date and Time** configuration tool, and doing so on the command line.

2.1. Using the Date and Time Configuration Tool

Fedora 17 is shipped with the **Date and Time** configuration tool, which allows you to change the date and time of the system, to configure the time zone used by the system, and to set up the Network Time Protocol daemon to synchronize the system clock with a time server. To start the tool, either select **Applications** **System Tools** **System Settings** from the **Activities** menu and click the **Date and Time** icon, or click the time in the panel and select **Date and Time Settings** from the drop-down menu.

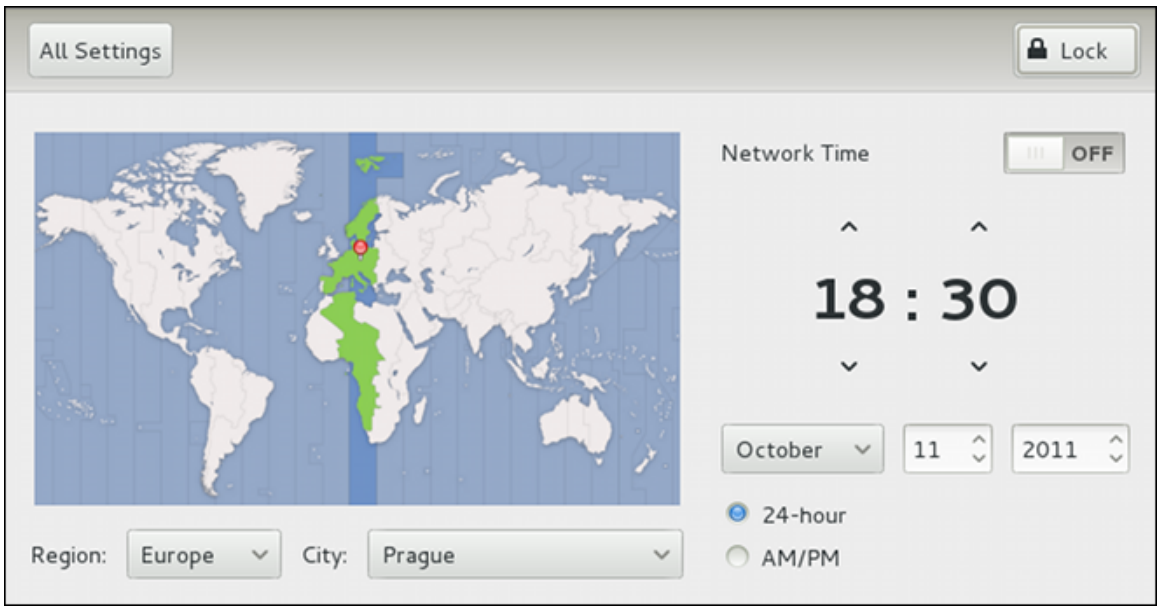


Figure 2.1. The Date and Time configuration tool

By default, the tool only allows you to review the current settings. This is because only `root` is allowed to set the system date and time. To unlock the configuration tool for changes, click the **Unlock** button in the top-right corner of the window, and provide the correct password when prompted.

To change the current time of your system, either configure the system to synchronize it over the network by clicking the **Network Time** switch, or set it manually by clicking the up and down arrows above and below the numbers. You can also select **24-hour** or **AM/PM** to enable or disable the 24-hour time format.

To change the time zone, either click on the map, or select the region and city from the **Region** and **City** drop-down lists.

To change the current date of your system, select a month from the drop-down list below the time, and use the up and down arrows to choose the day and year.

The changes take effect immediately.

2.2. Using the Command Line Tools

Fedora 17 provides command line tools that allow you to configure the date and time both manually and using the NTP protocol.

2.2.1. Changing the Date

To change the system date, type the following at a shell prompt as `root`:

```
date +%D -s YYYY-MM-DD
```

…where *YYYY* is a four-digit year, *MM* is a two-digit month, and *DD* is a two-digit day of the month. For example, to change the date to 2 June 2010, type:

```
~]# date +%D -s 2010-06-02
```

You can verify the current settings by running **date** without any additional argument.

2.2.2. Changing the Time

To change the current time, run the following command as `root`:

```
date +%T -s HH:MM:SS
```

…where *HH* stands for an hour, *MM* is a minute, and *SS* is a second, all typed in a two-digit form. If your system clock is set to use UTC (Coordinated Universal Time), also add the following option:

```
date +%T -s HH:MM:SS -u
```

For instance, to set the system clock to 11:26 PM using the UTC, type:

```
~]# date +%T -s 23:26:00 -u
```

You can verify the current settings by running **date** without any additional argument.

2.2.3. Configuring the Network Time Protocol

As opposed to the manual setup described above, you can also synchronize the system clock with a remote server over the Network Time Protocol (NTP). For the one-time synchronization only, use the **ntpdate** command:

1. Check whether the selected NTP server is accessible by using the **ntpdate** command in the following form:

   ```
   ntpdate -q server_address
   ```

   For example, to connect to `0.fedora.pool.ntp.org`, type:

   ```
   ~]$ ntpdate -q 0.fedora.pool.ntp.org
   ```

```
server 204.15.208.61, stratum 2, offset -39.275438, delay 0.16083
server 69.65.40.29, stratum 2, offset -39.269122, delay 0.17191
server 148.167.132.201, stratum 2, offset -39.270239, delay 0.20482
17 Oct 17:41:09 ntpdate[10619]: step time server 204.15.208.61 offset -39.275438 sec
```

2. When you find a satisfactory server, as `root`, run the **ntpdate** command followed with one or more server addresses:

```
ntpdate server_address…
```

For instance:

```
~]# ntpdate 0.fedora.pool.ntp.org 1.fedora.pool.ntp.org
17 Oct 17:42:13 ntpdate[10669]: step time server 204.15.208.61 offset -39.275436 sec
```

Unless an error message is displayed, the system time is now set. You can verify the current time by running the **date** command with no additional arguments.

3. In most cases, these steps are sufficient. Only if you really need one or more system services to always use the correct time, enable running the **ntpdate** at boot time by running the following command as `root`:

```
systemctl enable ntpdate.service
```

For more information about system services and their setup, refer to *Chapter 8, Services and Daemons*.



Note

If the synchronization with the time server at boot time keeps failing, that is, you find a relevant error message in the **/var/log/boot.log** system log, try to add the following line to **/etc/sysconfig/network**:

```
NETWORKWAIT=1
```

However, the more convenient way is to set the `ntpd` daemon to synchronize the time at boot time automatically:

1. As `root`, open the NTP configuration file **/etc/ntp.conf** in a text editor, creating a new one if it does not already exist.

2. Add or edit the list of public NTP servers. If you are using Fedora 17, the file should already contain the following lines, but feel free to change or expand these according to your needs:

```
server 0.fedora.pool.ntp.org iburst
server 1.fedora.pool.ntp.org iburst
server 2.fedora.pool.ntp.org iburst
```



Speeding up initial synchronization

To speed the initial synchronization up, it is recommended that the **iburst** directive is added at the end of each server line.

3. In the same file, set the proper permissions, giving the unrestricted access to localhost only:

```
restrict default kod nomodify notrap nopeer noquery
restrict -6 default kod nomodify notrap nopeer noquery
restrict 127.0.0.1
restrict -6 ::1
```

4. Save the changes, exit the editor, and restart the NTP daemon:

```
systemctl restart ntpd.service
```

5. Additionally, make sure that **ntpd** daemon is started at boot time:

```
systemctl enable ntpd.service
```

2.3. Additional Resources

For more information about the date and time configuration, refer to the following resources.

2.3.1. Installed Documentation

- **date**(1) — The manual page for the **date** utility.
- **ntpdate**(8) — The manual page for the **ntpdate** utility.
- **ntpd**(8) — The manual page for the `ntpd` service.

Managing Users and Groups

The control of users and groups is a core element of Fedora system administration. This chapter explains how to add, manage, and delete users and groups in the graphical user interface and on the command line, and covers advanced topics, such as enabling password aging or creating group directories.

3.1. Introduction to Users and Groups

While users can be either people (meaning accounts tied to physical users) or accounts which exist for specific applications to use, groups are logical expressions of organization, tying users together for a common purpose. Users within a group can read, write, or execute files owned by that group.

Each user is associated with a unique numerical identification number called a *user ID* (UID). Likewise, each group is associated with a *group ID* (GID). A user who creates a file is also the owner and group owner of that file. The file is assigned separate read, write, and execute permissions for the owner, the group, and everyone else. The file owner can be changed only by `root`, and access permissions can be changed by both the `root` user and file owner.

Additionally, Fedora supports *access control lists* (ACLs) for files and directories which allow permissions for specific users outside of the owner to be set. Refer to For more information about this feature, refer to the *Access Control Lists*[1] chapter of the *Storage Administration Guide*[2].

3.1.1. User Private Groups

Fedora uses a *user private group* (*UPG*) scheme, which makes UNIX groups easier to manage. A user private group is created whenever a new user is added to the system. It has the same name as the user for which it was created and that user is the only member of the user private group.

User private groups make it safe to set default permissions for a newly created file or directory, allowing both the user and *the group of that user* to make modifications to the file or directory.

The setting which determines what permissions are applied to a newly created file or directory is called a *umask* and is configured in the **`/etc/bashrc`** file. Traditionally on UNIX systems, the **`umask`** is set to **`022`**, which allows only the user who created the file or directory to make modifications. Under this scheme, all other users, *including members of the creator's group*, are not allowed to make any modifications. However, under the UPG scheme, this “group protection” is not necessary since every user has their own private group.

3.1.2. Shadow Passwords

Especially in environments with multiple users, it is very important to use *shadow passwords* provided by the *shadow-utils* package to enhance the security of system authentication files. For this reason, the installation program enables shadow passwords by default.

The following is a list of the advantages shadow passwords have over the traditional way of storing passwords on UNIX-based systems:

[1] http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Storage_Administration_Guide/ch-acls.html
[2] http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Storage_Administration_Guide/index.html

- Shadow passwords improve system security by moving encrypted password hashes from the world-readable **/etc/passwd** file to **/etc/shadow**, which is readable only by the root user.
- Shadow passwords store information about password aging.
- Shadow passwords allow the **/etc/login.defs** file to enforce security policies.

Most utilities provided by the *shadow-utils* package work properly whether or not shadow passwords are enabled. However, since password aging information is stored exclusively in the **/etc/shadow** file, any commands which create or modify password aging information do not work. The following is a list of utilities and commands that do not work without first enabling shadow passwords:

- The **chage** utility.
- The **gpasswd** utility.
- The **usermod** command with the **-e** or **-f** option.
- The **useradd** command with the **-e** or **-f** option.

3.2. Using the User Accounts Tool

The **User Accounts** configuration tool allows you to view, modify, add, and delete local users. To run the tool, select **Applications** → **System Tools** → **System Settings** from the **Activities** menu and click the **User Accounts** icon.

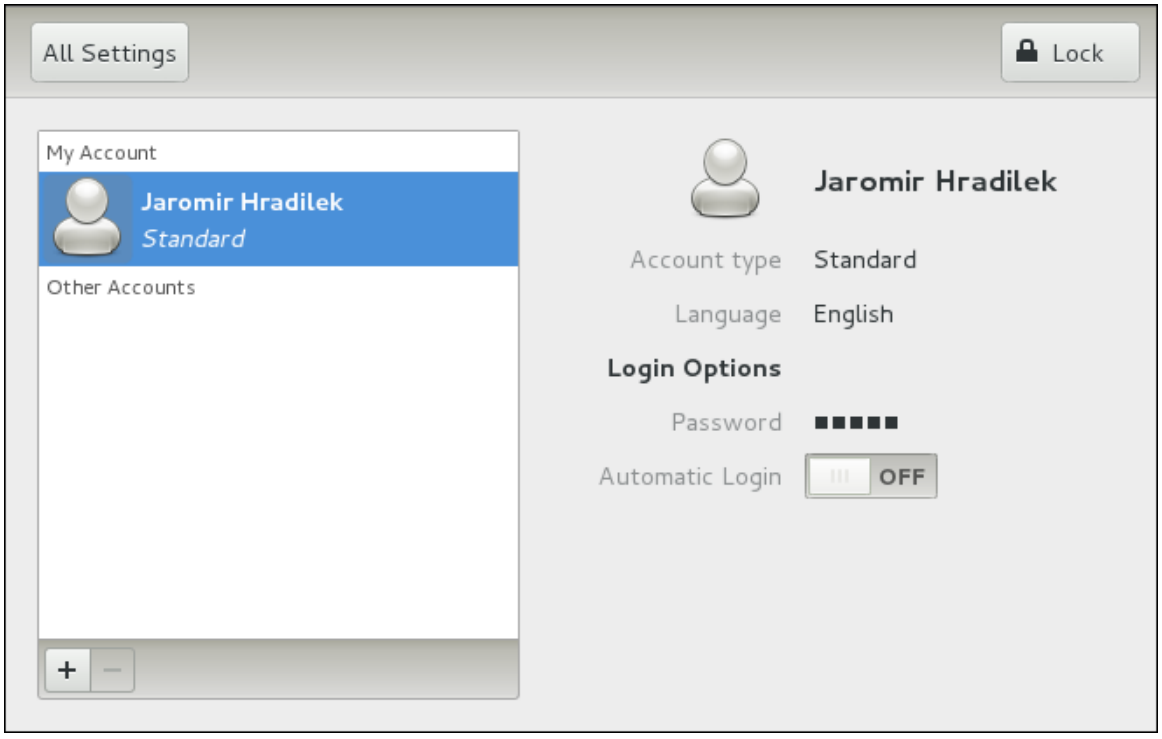


Figure 3.1. The User Accounts configuration tool

By default, the tool only allows you to change certain settings regarding your account. This is because only the root user is allowed to configure users and groups. To unlock the configuration tool for all kinds of changes, click the **Unlock** button in the top-right corner of the window, and provide the correct password when prompted.

3.2.1. Configuring an Account

To change the image associated with an account, click the icon next to the account name and either select a picture from the pulldown list, or click **Browse for more pictures...** to use an image from your local drive.

To change the name associated with an account, click the name next to the icon to edit it.

To change the account type, click the text next to the **Account type** label. Note that this change requires the configuration tool to be unlocked even if you are changing your own account.

To change the default language for an account, click the text next to the **Language** label and select a language from the list.

To change the password, click the field next to the **Password** label. A dialog box appears, allowing you to set the new password. Note that the current password must be provided in order to confirm the change. Once done, click the **Change** button to save the change.

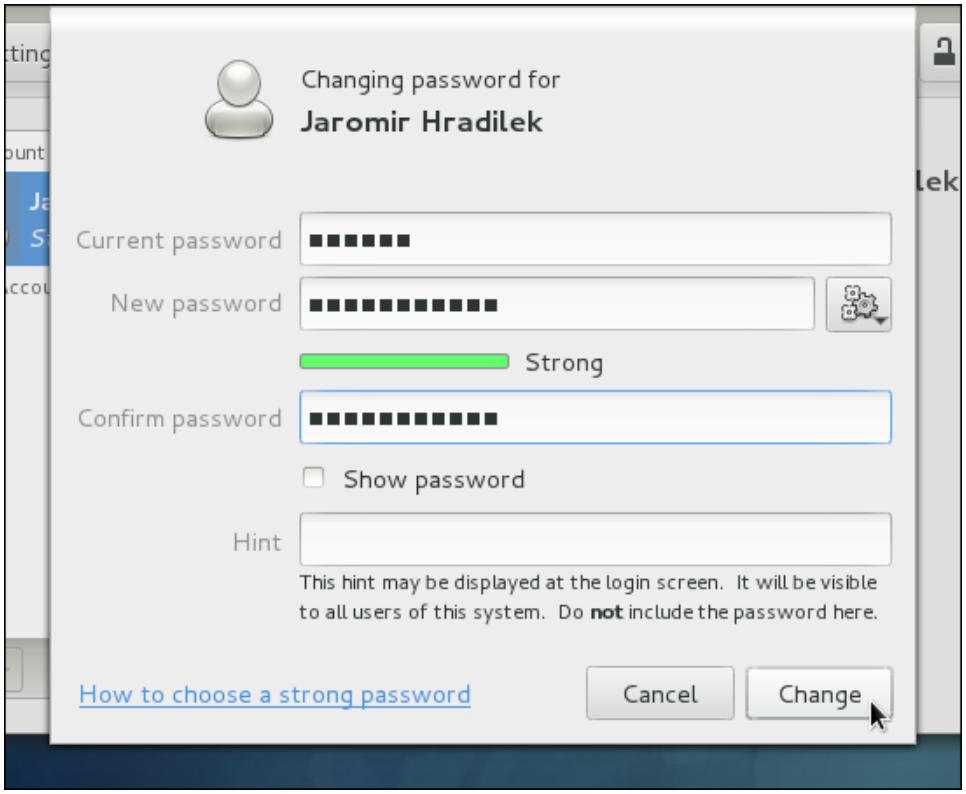


Figure 3.2. Changing the password

Password security advice

It is advisable to use a much longer password, as this makes it more difficult for an intruder to guess it and access the account without permission. It is also recommended that the password not be based on a dictionary term: use a combination of letters, numbers and special characters.

Finally, to set up automatic login for a particular account, enable the **Automatic Login** switch. The configuration tool must be unlocked to make this change.

3.2.2. Adding a New User

To add a new user, make sure the configuration tool is unlocked, and click the **+** button (that is, the plus sign) below the account list. A dialog window appears, allowing you to supply user details.

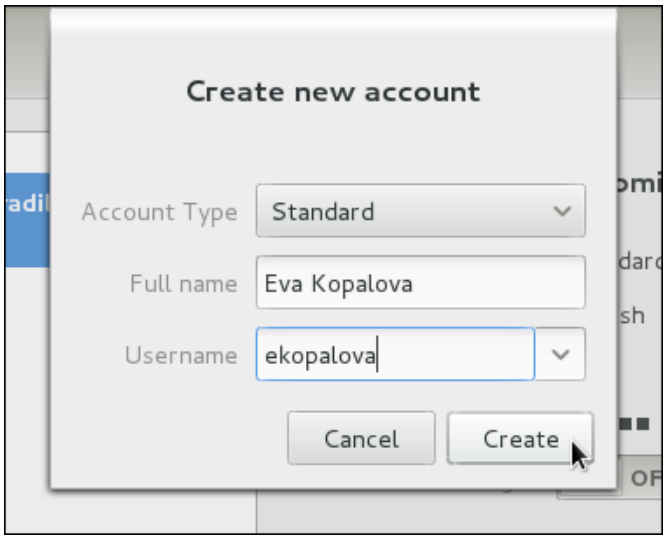


Figure 3.3. Creating a new account

Take the following steps to create an account:

1. Select an account type from the **Account type** pulldown list. Available account types are **`Administrator`** and **`Standard`** (the default option).
2. Fill in the **Full name** input field to set the name associated with the account. This name will be used by the login manager, and will be displayed on the panel.
3. Either select a suggested username from the **Username** pulldown list, or fill in the corresponding input field.
4. Click the **Create** button to confirm the settings.

Fedora uses a *user private group* (UPG) scheme. The UPG scheme does not add or change anything in the standard UNIX way of handling groups; it offers a new convention. Whenever you create a new user, a unique group with the same name as the user is created.

When a new account is created, default configuration files are copied from the **`/etc/skel/`** directory into the new home directory.

3.2.3. Removing a User

To remove a user, make sure the configuration tool is unlocked, select the desired account from the account list, and click the **−** button (that is, the minus sign) below the account list. A dialog window appears, allowing you to confirm or cancel the change.

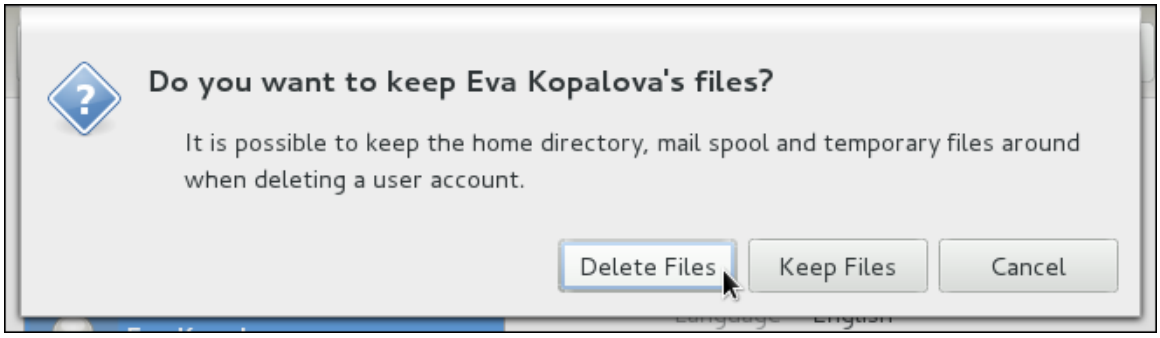


Figure 3.4. Removing an account

To delete files and directories that belong to the user (that is, the home directory, mail spool, and temporary files), click the **Delete Files** button. To keep these files intact and only delete the user account, click **Keep Files**. To abort the deletion, click **Cancel**.

3.3. Using the User Manager Tool

The **User Manager** application allows you to view, modify, add, and delete local users and groups in the graphical user interface. To start the application, either select **Applications** **Other** **Users and Groups** from the **Activities** menu, or type **`system-config-users`** at a shell prompt. Note that unless you have superuser privileges, the application will prompt you to authenticate as `root`.

3.3.1. Viewing Users and Groups

The main window of the **User Manager** is divided into two tabs: The **Users** tab provides a list of local users along with additional information about their user ID, primary group, home directory, login shell, and full name. The **Groups** tab provides a list of local groups with information about their group ID and group members.

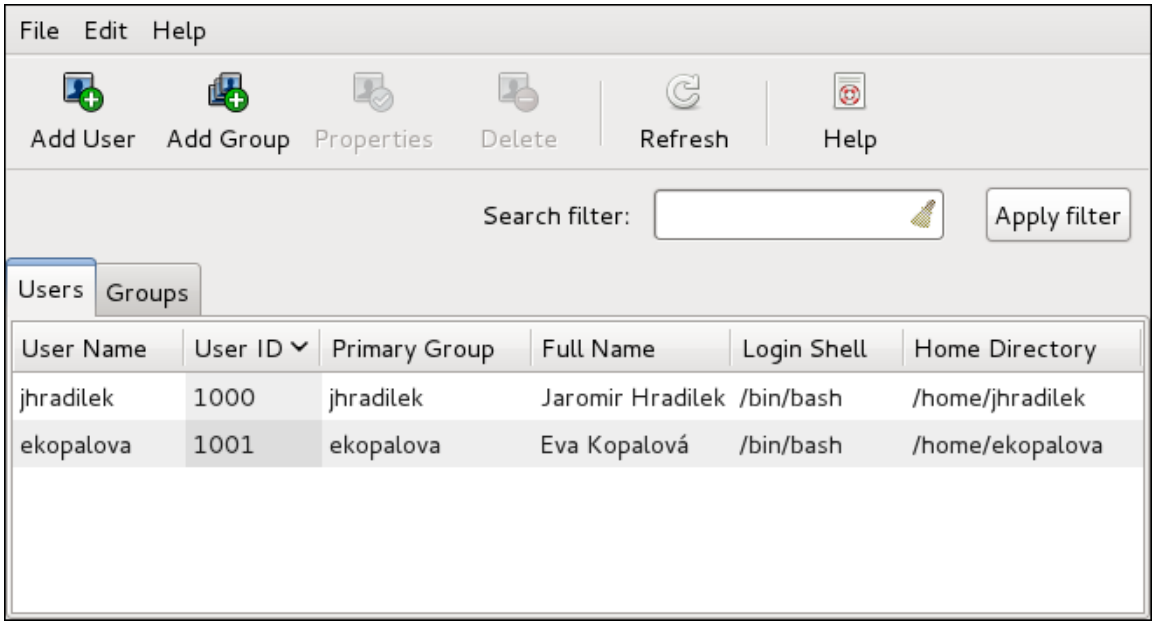


Figure 3.5. Viewing users and groups

To find a specific user or group, type the first few letters of the name in the **Search filter** field and either press **Enter**, or click the **Apply filter** button. You can also sort the items according to any of the available columns by clicking the column header.

Fedora reserves user and group IDs below 1000 for system users and groups. By default, the **User Manager** does not display the system users. To view all users and groups, select **Edit** **Preferences** to open the **Preferences** dialog box, and clear the **Hide system users and groups** check box.

3.3.2. Adding a New User

To add a new user, click the **Add User** button. A window as shown in *Figure 3.6, "Adding a new user"* appears.

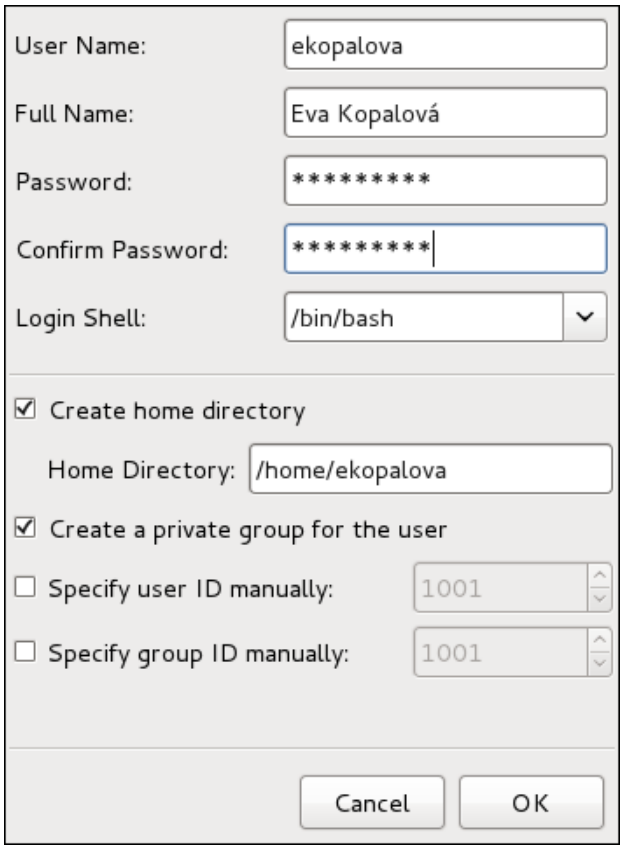


Figure 3.6. Adding a new user

The **Add New User** dialog box allows you to provide information about the newly created user. In order to create a user, enter the username and full name in the appropriate fields and then type the user's password in the **Password** and **Confirm Password** fields. The password must be at least six characters long.



Password security advice

It is advisable to use a much longer password, as this makes it more difficult for an intruder to guess it and access the account without permission. It is also recommended that the password not be based on a dictionary term: use a combination of letters, numbers and special characters.

The **Login Shell** pulldown list allows you to select a login shell for the user. If you are not sure which shell to select, accept the default value of **/bin/bash**.

By default, the **User Manager** application creates the home directory for a new user in **/home/*username*/**. You can choose not to create the home directory by clearing the **Create home directory** check box, or change this directory by editing the content of the **Home Directory** text box. Note that when the home directory is created, default configuration files are copied into it from the **/etc/skel/** directory.

Fedora uses a user private group (UPG) scheme. Whenever you create a new user, a unique group with the same name as the user is created by default. If you do not want to create this group, clear the **Create a private group for the user** check box.

To specify a user ID for the user, select **Specify user ID manually**. If the option is not selected, the next available user ID above 1000 is assigned to the new user. Because Fedora reserves user IDs below 1000 for system users, it is not advisable to manually assign user IDs 1–999.

Clicking the **OK** button creates the new user. To configure more advanced user properties, such as password expiration, modify the user's properties after adding the user.

3.3.3. Adding a New Group

To add a new user group, select **Add Group** from the toolbar. A window similar to *Figure 3.7, "New Group"* appears. Type the name of the new group. To specify a group ID for the new group, select **Specify group ID manually** and select the GID. Note that Fedora also reserves group IDs lower than 1000 for system groups.

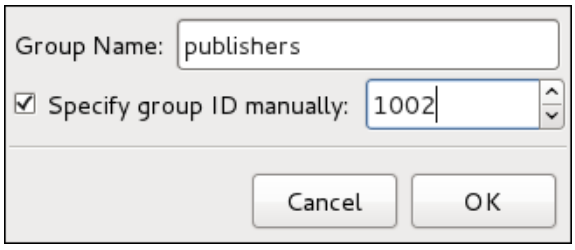


Figure 3.7. New Group

Click **OK** to create the group. The new group appears in the group list.

3.3.4. Modifying User Properties

To view the properties of an existing user, click on the **Users** tab, select the user from the user list, and click **Properties** from the menu (or choose **File□□□ Properties** from the pulldown menu). A window similar to *Figure 3.8, "User Properties"* appears.

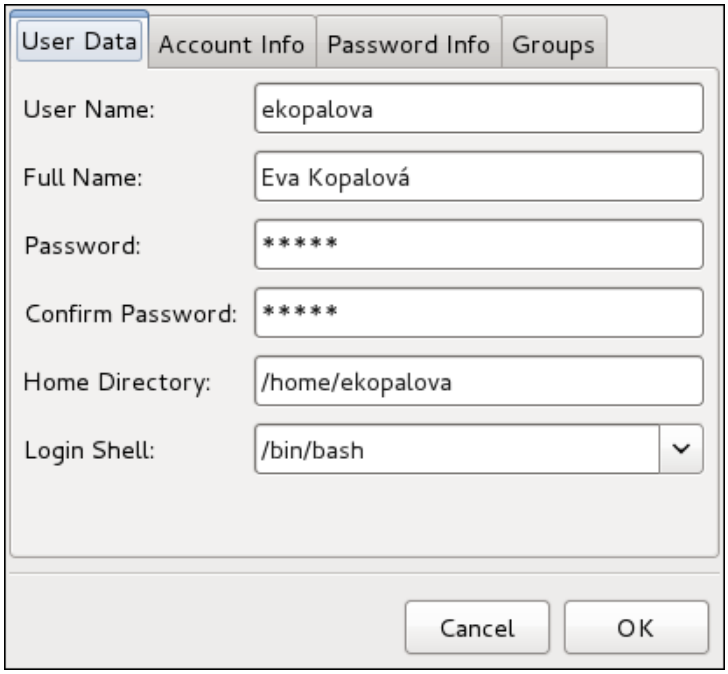


Figure 3.8. User Properties

The **User Properties** window is divided into multiple tabbed pages:

- **User Data** — Shows the basic user information configured when you added the user. Use this tab to change the user's full name, password, home directory, or login shell.
- **Account Info** — Select **Enable account expiration** if you want the account to expire on a certain date. Enter the date in the provided fields. Select **Local password is locked** to lock the user account and prevent the user from logging into the system.
- **Password Info** — Displays the date that the user's password last changed. To force the user to change passwords after a certain number of days, select **Enable password expiration** and enter a desired value in the **Days before change required:** field. The number of days before the user's password expires, the number of days before the user is warned to change passwords, and days before the account becomes inactive can also be changed.
- **Groups** — Allows you to view and configure the Primary Group of the user, as well as other groups that you want the user to be a member of.

3.3.5. Modifying Group Properties

To view the properties of an existing group, select the group from the group list and click **Properties** from the menu (or choose **File□□□ Properties** from the pulldown menu). A window similar to *Figure 3.9, "Group Properties"* appears.

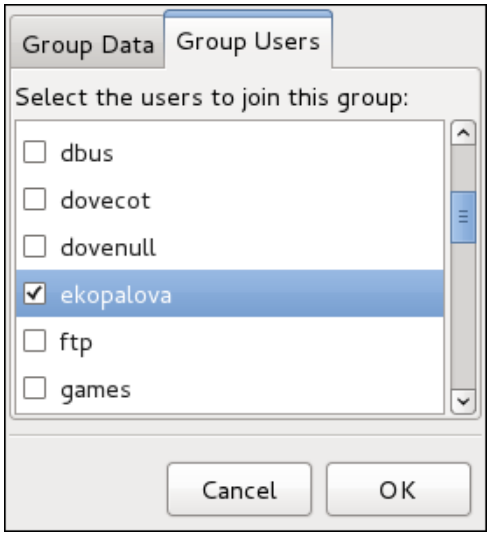


Figure 3.9. Group Properties

The **Group Users** tab displays which users are members of the group. Use this tab to add or remove users from the group. Click **OK** to save your changes.

3.4. Using Command Line Tools

The easiest say to manage users and groups on Fedora is to use the **User Manager** application as described in *Section 3.3, "Using the User Manager Tool"*. However, if you prefer command line tools or do not have the X Window System installed, you can use command line utilities that are listed in *Table 3.1, "Command line utilities for managing users and groups"*.

Table 3.1. Command line utilities for managing users and groups

Utilities	Description
useradd, **usermod**, **userdel**	Standard utilities for adding, modifying, and deleting user accounts.
groupadd, **groupmod**, **groupdel**	Standard utilities for adding, modifying, and deleting groups.
gpasswd	Standard utility for administering the **/etc/group** configuration file.
pwck, **grpck**	Utilities that can be used for verification of the password, group, and associated shadow files.
pwconv, **pwunconv**	Utilities that can be used for the conversion of passwords to shadow passwords, or back from shadow passwords to standard passwords.

3.4.1. Adding a New User

To add a new user to the system, typing the following at a shell prompt as `root`:

```
useradd [options] username
```

…where *options* are command line options as described in *Table 3.2, "useradd command line options"*.

By default, the **useradd** command creates a locked user account. To unlock the account, run the following command as `root` to assign a password:

```
passwd username
```

Optionally, you can set password aging policy. Refer to *Section 3.4.3, "Enabling Password Aging"* for information on how to enable password aging.

Table 3.2. useradd command line options

Option	Description
-c '*comment*'	*comment* can be replaced with any string. This option is generally used to specify the full name of a user.
-d *home_directory*	Home directory to be used instead of default **/home/*username*/**.
-e *date*	Date for the account to be disabled in the format YYYY-MM-DD.
-f *days*	Number of days after the password expires until the account is disabled. If **0** is specified, the account is disabled immediately after the password expires. If **-1** is specified, the account is not be disabled after the password expires.
-g *group_name*	Group name or group number for the user's default group. The group must exist prior to being specified here.
-G *group_list*	List of additional (other than default) group names or group numbers, separated by commas, of which the user is a member. The groups must exist prior to being specified here.
-m	Create the home directory if it does not exist.
-M	Do not create the home directory.
-N	Do not create a user private group for the user.
-p *password*	The password encrypted with **crypt**.
-r	Create a system account with a UID less than 1000 and without a home directory.
-s	User's login shell, which defaults to **/bin/bash**.
-u *uid*	User ID for the user, which must be unique and greater than 999.

Explaining the Process

The following steps illustrate what happens if the command **useradd juan** is issued on a system that has shadow passwords enabled:

1. A new line for `juan` is created in **/etc/passwd**:

   ```
   juan:x:501:501::/home/juan:/bin/bash
   ```

   The line has the following characteristics:

   - It begins with the username `juan`.
   - There is an **x** for the password field indicating that the system is using shadow passwords.
   - A UID greater than 999 is created. Under Fedora, UIDs below 1000 are reserved for system use and should not be assigned to users.

- A GID greater than 999 is created. Under Fedora, GIDs below 1000 are reserved for system use and should not be assigned to users.
- The optional *GECOS* information is left blank.
- The home directory for `juan` is set to **`/home/juan/`**.
- The default shell is set to **`/bin/bash`**.

2. A new line for `juan` is created in **`/etc/shadow`**:

```
juan:!!:14798:0:99999:7:::
```

The line has the following characteristics:

- It begins with the username `juan`.
- Two exclamation marks (**`!!`**) appear in the password field of the **`/etc/shadow`** file, which locks the account.



Note

If an encrypted password is passed using the **`-p`** flag, it is placed in the **`/etc/shadow`** file on the new line for the user.

- The password is set to never expire.

3. A new line for a group named `juan` is created in **`/etc/group`**:

```
juan:x:501:
```

A group with the same name as a user is called a *user private group*. For more information on user private groups, refer to *Section 3.1.1, "User Private Groups"*.

The line created in **`/etc/group`** has the following characteristics:

- It begins with the group name `juan`.
- An **`x`** appears in the password field indicating that the system is using shadow group passwords.
- The GID matches the one listed for user `juan` in **`/etc/passwd`**.

4. A new line for a group named `juan` is created in **`/etc/gshadow`**:

```
juan:!::
```

The line has the following characteristics:

- It begins with the group name `juan`.

- An exclamation mark (**!**) appears in the password field of the **/etc/gshadow** file, which locks the group.
- All other fields are blank.

5. A directory for user `juan` is created in the **/home/** directory:

```
~]# ls -l /home
total 4
drwx------. 4 juan juan 4096 Mar  3 18:23 juan
```

This directory is owned by user `juan` and group `juan`. It has *read*, *write*, and *execute* privileges *only* for the user `juan`. All other permissions are denied.

6. The files within the **/etc/skel/** directory (which contain default user settings) are copied into the new **/home/juan/** directory:

```
~]# ls -la /home/juan
total 28
drwx------. 4 juan juan 4096 Mar  3 18:23 .
drwxr-xr-x. 5 root root 4096 Mar  3 18:23 ..
-rw-r--r--. 1 juan juan   18 Jun 22  2010 .bash_logout
-rw-r--r--. 1 juan juan  176 Jun 22  2010 .bash_profile
-rw-r--r--. 1 juan juan  124 Jun 22  2010 .bashrc
drwxr-xr-x. 2 juan juan 4096 Jul 14  2010 .gnome2
drwxr-xr-x. 4 juan juan 4096 Nov 23 15:09 .mozilla
```

At this point, a locked account called `juan` exists on the system. To activate it, the administrator must next assign a password to the account using the **passwd** command and, optionally, set password aging guidelines.

3.4.2. Adding a New Group

To add a new group to the system, type the following at a shell prompt as `root`:

```
groupadd [options] group_name
```

…where *options* are command line options as described in *Table 3.3, "groupadd command line options"*.

Table 3.3. groupadd command line options

Option	Description
-f, **--force**	When used with **-g** *gid* and *gid* already exists, **groupadd** will choose another unique *gid* for the group.
-g *gid*	Group ID for the group, which must be unique and greater than 999.
-K, **--key** *key=value*	Override **/etc/login.defs** defaults.
-o, **--non-unique**	Allow to create groups with duplicate.
-p, **--password** *password*	Use this encrypted password for the new group.
-r	Create a system group with a GID less than 1000.

3.4.3. Enabling Password Aging

For security reasons, it is advisable to require users to change their passwords periodically. This can either be done when adding or editing a user on the **Password Info** tab of the **User Manager** application, or by using the **chage** command.



Shadow passwords must be enabled to use chage

Shadow passwords must be enabled to use the **chage** command. For more information, see *Section 3.1.2, "Shadow Passwords"*.

To configure password expiration for a user from a shell prompt, run the following command as `root`:

```
chage [options] username
```

…where *options* are command line options as described in *Table 3.4, "chage command line options"*. When the **chage** command is followed directly by a username (that is, when no command line options are specified), it displays the current password aging values and allows you to change them interactively.

Table 3.4. chage command line options

Option	Description
-d *days*	Specifies the number of days since January 1, 1970 the password was changed.
-E *date*	Specifies the date on which the account is locked, in the format YYYY-MM-DD. Instead of the date, the number of days since January 1, 1970 can also be used.
-I *days*	Specifies the number of inactive days after the password expiration before locking the account. If the value is **0**, the account is not locked after the password expires.
-l	Lists current account aging settings.
-m *days*	Specify the minimum number of days after which the user must change passwords. If the value is **0**, the password does not expire.
-M *days*	Specify the maximum number of days for which the password is valid. When the number of days specified by this option plus the number of days specified with the **-d** option is less than the current day, the user must change passwords before using the account.
-W *days*	Specifies the number of days before the password expiration date to warn the user.

You can configure a password to expire the first time a user logs in. This forces users to change passwords immediately.

1. Set up an initial password. There are two common approaches to this step: you can either assign a default password, or you can use a null password.

   To assign a default password, type the following at a shell prompt as `root`:

```
passwd username
```

To assign a null password instead, use the following command:

```
passwd -d username
```



Avoid using null passwords whenever possible

Using a null password, while convenient, is a highly insecure practice, as any third party can log in first and access the system using the insecure username. Always make sure that the user is ready to log in before unlocking an account with a null password.

2. Force immediate password expiration by running the following command as `root`:

```
chage -d 0 username
```

This command sets the value for the date the password was last changed to the epoch (January 1, 1970). This value forces immediate password expiration no matter what password aging policy, if any, is in place.

Upon the initial log in, the user is now prompted for a new password.

3.4.4. Enabling Automatic Logouts

Especially when the user is logged in as `root`, an unattended login session may pose a significant security risk. To reduce this risk, you can configure the system to automatically log out idle users after a fixed period of time:

1. Make sure the *screen* package is installed. You can do so by running the following command as `root`:

```
yum install screen
```

For more information on how to install packages in Fedora, refer to *Section 4.2.4, "Installing Packages"*.

2. As `root`, add the following line at the beginning of the **`/etc/profile`** file to make sure the processing of this file cannot be interrupted:

```
trap "" 1 2 3 15
```

3. Add the following lines at the end of the **`/etc/profile`** file to start a **`screen`** session each time a user logs in to a virtual console or remotely:

```
SCREENEXEC="screen"
if [ -w $(tty) ]; then
  trap "exec $SCREENEXEC" 1 2 3 15
  echo -n 'Starting session in 10 seconds'
```

```
  sleep 10
  exec $SCREENEXEC
fi
```

Note that each time a new session starts, a message will be displayed and the user will have to wait ten seconds. To adjust the time to wait before starting a session, change the value after the **sleep** command.

4. Add the following lines to the **/etc/screenrc** configuration file to close the **screen** session after a given period of inactivity:

```
idle 120 quit
autodetach off
```

This will set the time limit to 120 seconds. To adjust this limit, change the value after the **idle** directive.

Alternatively, you can configure the system to only lock the session by using the following lines instead:

```
idle 120 lockscreen
autodetach off
```

This way, a password will be required to unlock the session.

The changes take effect the next time a user logs in to the system.

3.4.5. Creating Group Directories

System administrators usually like to create a group for each major project and assign people to the group when they need to access that project's files. With this traditional scheme, file managing is difficult; when someone creates a file, it is associated with the primary group to which they belong. When a single person works on multiple projects, it becomes difficult to associate the right files with the right group. However, with the UPG scheme, groups are automatically assigned to files created within a directory with the *setgid* bit set. The setgid bit makes managing group projects that share a common directory very simple because any files a user creates within the directory are owned by the group which owns the directory.

For example, a group of people need to work on files in the **/opt/myproject/** directory. Some people are trusted to modify the contents of this directory, but not everyone.

1. As `root`, create the **/opt/myproject/** directory by typing the following at a shell prompt:

```
mkdir /opt/myproject
```

2. Add the `myproject` group to the system:

```
groupadd myproject
```

3. Associate the contents of the **/opt/myproject/** directory with the `myproject` group:

```
chown root:myproject /opt/myproject
```

4. Allow users to create files within the directory, and set the setgid bit:

```
chmod 2775 /opt/myproject
```

At this point, all members of the `myproject` group can create and edit files in the **`/opt/myproject/`** directory without the administrator having to change file permissions every time users write new files. To verify that the permissions have been set correctly, run the following command:

```
~]# ls -l /opt
total 4
drwxrwsr-x. 3 root myproject 4096 Mar  3 18:31 myproject
```

3.5. Additional Resources

Refer to the following resources for more information about managing users and groups.

3.5.1. Installed Documentation

For information about various utilities for managing users and groups, refer to the following manual pages:

- **chage**(1) — A command to modify password aging policies and account expiration.
- **gpasswd**(1) — A command to administer the **`/etc/group`** file.
- **groupadd**(8) — A command to add groups.
- **grpck**(8) — A command to verify the **`/etc/group`** file.
- **groupdel**(8) — A command to remove groups.
- **groupmod**(8) — A command to modify group membership.
- **pwck**(8) — A command to verify the **`/etc/passwd`** and **`/etc/shadow`** files.
- **pwconv**(8) — A tool to convert standard passwords to shadow passwords.
- **pwunconv**(8) — A tool to convert shadow passwords to standard passwords.
- **useradd**(8) — A command to add users.
- **userdel**(8) — A command to remove users.
- **usermod**(8) — A command to modify users.

For information about related configuration files, see:

- **group**(5) — The file containing group information for the system.
- **passwd**(5) — The file containing user information for the system.
- **shadow**(5) — The file containing passwords and account expiration information for the system.

Part II. Package Management

All software on a Fedora system is divided into RPM packages, which can be installed, upgraded, or removed. This part describes how to manage packages on Fedora using both **Yum** and the **PackageKit** suite of graphical package management tools.

Yum

Yum is the The Fedora Project package manager that is able to query for information about packages, fetch packages from repositories, install and uninstall packages using automatic dependency resolution, and update an entire system to the latest available packages. Yum performs automatic dependency resolution on packages you are updating, installing or removing, and thus is able to automatically determine, fetch and install all available dependent packages. Yum can be configured with new, additional repositories, or *package sources*, and also provides many plug-ins which enhance and extend its capabilities. Yum is able to perform many of the same tasks that **RPM** can; additionally, many of the command line options are similar. Yum enables easy and simple package management on a single machine or on groups of them.



Secure package management with GPG-signed packages

Yum provides secure package management by enabling GPG (Gnu Privacy Guard; also known as GnuPG) signature verification on GPG-signed packages to be turned on for all package repositories (i.e. package sources), or for individual repositories. When signature verification is enabled, Yum will refuse to install any packages not GPG-signed with the correct key for that repository. This means that you can trust that the **RPM** packages you download and install on your system are from a trusted source, such as The Fedora Project, and were not modified during transfer. Refer to *Section 4.3, "Configuring Yum and Yum Repositories"* for details on enabling signature-checking with Yum, or *Section B.3, "Checking a Package's Signature"* for information on working with and verifying GPG-signed **RPM** packages in general.

Yum also enables you to easily set up your own repositories of **RPM** packages for download and installation on other machines.

Learning Yum is a worthwhile investment because it is often the fastest way to perform system administration tasks, and it provides capabilities beyond those provided by the **PackageKit** graphical package management tools. Refer to *Chapter 5, PackageKit* for details on using **PackageKit**.



Yum and superuser privileges

You must have superuser privileges in order to use **yum** to install, update or remove packages on your system. All examples in this chapter assume that you have already obtained superuser privileges by using either the **su** or **sudo** command.

4.1. Checking For and Updating Packages

4.1.1. Checking For Updates

To see which installed packages on your system have updates available, use the following command:

```
yum check-update
```

For example:

```
~]# yum check-update
Loaded plugins: langpacks, presto, refresh-packagekit

PackageKit.x86_64                     0.6.14-2.fc15                fedora
PackageKit-command-not-found.x86_64   0.6.14-2.fc15                fedora
PackageKit-device-rebind.x86_64       0.6.14-2.fc15                fedora
PackageKit-glib.x86_64                0.6.14-2.fc15                fedora
PackageKit-gstreamer-plugin.x86_64    0.6.14-2.fc15                fedora
PackageKit-gtk-module.x86_64          0.6.14-2.fc15                fedora
PackageKit-gtk3-module.x86_64         0.6.14-2.fc15                fedora
PackageKit-yum.x86_64                 0.6.14-2.fc15                fedora
PackageKit-yum-plugin.x86_64          0.6.14-2.fc15                fedora
gdb.x86_64                            7.2.90.20110429-36.fc15      fedora
kernel.x86_64                         2.6.38.6-26.fc15             fedora
rpm.x86_64                            4.9.0-6.fc15                 fedora
rpm-libs.x86_64                       4.9.0-6.fc15                 fedora
rpm-python.x86_64                     4.9.0-6.fc15                 fedora
yum.noarch                            3.2.29-5.fc15                fedora
```

The packages in the above output are listed as having updates available. The first package in the list is **PackageKit**, the graphical package manager. The line in the example output tells us:

- **`PackageKit`** — the name of the package
- **`x86_64`** — the CPU architecture the package was built for
- **`0.6.14`** — the version of the updated package to be installed
- **`fedora`** — the repository in which the updated package is located

The output also shows us that we can update the kernel (the kernel package), Yum and **RPM** themselves (the **`yum`** and **`rpm`** packages), as well as their dependencies (such as the *kernel-firmware*, *rpm-libs*, and *rpm-python* packages), all using **`yum`**.

4.1.2. Updating Packages

You can choose to update a single package, multiple packages, or all packages at once. If any dependencies of the package (or packages) you update have updates available themselves, then they are updated too.

Updating a Single Package

To update a single package, run the following command as `root`:

```
yum update package_name
```

For example, to update the *udev* package, type:

```
~]# yum update udev
Loaded plugins: langpacks, presto, refresh-packagekit
Updating Red Hat repositories.
INFO:rhsm-app.repolib:repos updated: 0
Setting up Update Process
Resolving Dependencies
--> Running transaction check
---> Package gdb.x86_64 0:7.2.90.20110411-34.fc15 will be updated
```

```
---> Package gdb.x86_64 0:7.2.90.20110429-36.fc15 will be an update
--> Finished Dependency Resolution

Dependencies Resolved

================================================================================
 Package     Arch         Version                          Repository      Size
================================================================================
Updating:
 gdb         x86_64       7.2.90.20110429-36.fc15          fedora         1.9 M

Transaction Summary
================================================================================
Upgrade       1 Package(s)

Total download size: 1.9 M
Is this ok [y/N]:
```

This output contains several items of interest:

1. **`Loaded plugins:`** — **`yum`** always informs you which **Yum** plug-ins are installed and enabled. Here, **`yum`** is using the **langpacks**, **presto**, and **refresh-packagekit** plug-ins. Refer to *Section 4.4, "Yum Plug-ins"* for general information on **Yum** plug-ins, or to *Section 4.4.3, "Plug-in Descriptions"* for descriptions of specific plug-ins.

2. **`gdb.x86_64`** — you can download and install new *gdb* package.

3. **`yum`** presents the update information and then prompts you as to whether you want it to perform the update; **`yum`** runs interactively by default. If you already know which transactions **`yum`** plans to perform, you can use the **`-y`** option to automatically answer **`yes`** to any questions **`yum`** may ask (in which case it runs non-interactively). However, you should always examine which changes **`yum`** plans to make to the system so that you can easily troubleshoot any problems that might arise.

   If a transaction does go awry, you can view Yum's transaction history by using the **`yum history`** command as described in *Section 4.2.6, "Working with Transaction History"*.



Updating and installing kernels with Yum

`yum` always *installs* a new kernel in the same sense that **RPM** installs a new kernel when you use the command **`rpm -i kernel`**. Therefore, you do not need to worry about the distinction between *installing* and *upgrading* a kernel package when you use **`yum`**: it will do the right thing, regardless of whether you are using the **`yum update`** or **`yum install`** command.

When using **RPM**, on the other hand, it is important to use the **`rpm -i kernel`** command (which installs a new kernel) instead of **`rpm -u kernel`** (which *replaces* the current kernel). Refer to *Section B.2.2, "Installing and Upgrading"* for more information on installing/updating kernels with **RPM**.

Updating All Packages and Their Dependencies

To update all packages and their dependencies, simply enter **`yum update`** (without any arguments):

```
yum update
```

Updating Security-Related Packages

Discovering which packages have security updates available and then updating those packages quickly and easily is important. Yum provides the plug-in for this purpose. The **security** plug-in extends the **yum** command with a set of highly-useful security-centric commands, subcommands and options. Refer to *Section 4.4.3, "Plug-in Descriptions"* for specific information.

4.1.3. Preserving Configuration File Changes

You will inevitably make changes to the configuration files installed by packages as you use your Fedora system. **RPM**, which Yum uses to perform changes to the system, provides a mechanism for ensuring their integrity. Refer to *Section B.2.2, "Installing and Upgrading"* for details on how to manage changes to configuration files across package upgrades.

4.2. Packages and Package Groups

4.2.1. Searching Packages

You can search all RPM package names, descriptions and summaries by using the following command:

```
yum search term…
```

This command displays the list of matches for each term. For example, to list all packages that match "meld" or "kompare", type:

```
~]# yum search meld kompare
Loaded plugins: langpacks, presto, refresh-packagekit
============================== N/S Matched: meld ===============================
meld.noarch : Visual diff and merge tool
python-meld3.x86_64 : HTML/XML templating system for Python

============================== N/S Matched: kompare ============================
komparator.x86_64 : Kompare and merge two folders

  Name and summary matches only, use "search all" for everything.
```

The **yum search** command is useful for searching for packages you do not know the name of, but for which you know a related term.

4.2.2. Listing Packages

yum list and related commands provide information about packages, package groups, and repositories.

All of Yum's list commands allow you to filter the results by appending one or more *glob expressions* as arguments. Glob expressions are normal strings of characters which contain one or more of the wildcard characters ***** (which expands to match any character multiple times) and **?** (which expands to match any one character).



Filtering results with glob expressions

Be careful to escape the glob expressions when passing them as arguments to a **yum** command, otherwise the Bash shell will interpret these expressions as *pathname expansions*, and potentially pass all files in the current directory that match the globs to **yum**. To make sure the glob expressions are passed to **yum** as intended, either:

- escape the wildcard characters by preceding them with a backslash character
- double-quote or single-quote the entire glob expression.

Refer to *Example 4.1, "Listing all ABRT addons and plug-ins using glob expressions"* and *Example 4.4, "Listing available packages using a single glob expression with escaped wildcard characters"* for an example usage of both these methods.

yum list *glob_expression*…

Lists information on installed and available packages matching all glob expressions.

Example 4.1. Listing all ABRT addons and plug-ins using glob expressions

Packages with various ABRT addons and plug-ins either begin with "abrt-addon-", or "abrt-plugin-". To list these packages, type the following at a shell prompt:

```
~]# yum list abrt-addon\* abrt-plugin\*
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
abrt-addon-ccpp.x86_64               2.0.2-5.fc15     @fedora
abrt-addon-kerneloops.x86_64         2.0.2-5.fc15     @fedora
abrt-addon-python.x86_64             2.0.2-5.fc15     @fedora
abrt-plugin-bugzilla.x86_64          2.0.2-5.fc15     @fedora
abrt-plugin-logger.x86_64            2.0.2-5.fc15     @fedora
Available Packages
abrt-plugin-mailx.x86_64             2.0.2-5.fc15     updates
abrt-plugin-reportuploader.x86_64    2.0.2-5.fc15     updates
abrt-plugin-rhtsupport.x86_64        2.0.2-5.fc15     updates
```

yum list all

Lists all installed *and* available packages.

Example 4.2. Listing all installed and available packages

```
~]# yum list all
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
ConsoleKit.x86_64                       0.4.4-1.fc15                 @fedora
ConsoleKit-libs.x86_64                  0.4.4-1.fc15                 @fedora
ConsoleKit-x11.x86_64                   0.4.4-1.fc15                 @fedora
GConf2.x86_64                           2.32.3-1.fc15                @fedora
GConf2-gtk.x86_64                       2.32.3-1.fc15                @fedora
ModemManager.x86_64                     0.4-7.git20110201.fc15       @fedora
NetworkManager.x86_64                   1:0.8.998-4.git20110427.fc15 @fedora
NetworkManager-glib.x86_64              1:0.8.998-4.git20110427.fc15 @fedora
NetworkManager-gnome.x86_64             1:0.8.998-4.git20110427.fc15 @fedora
```

```
NetworkManager-openconnect.x86_64       0.8.1-9.git20110419.fc15      @fedora
[output truncated]
```

yum list installed

Lists all packages installed on your system. The rightmost column in the output lists the repository from which the package was retrieved.

Example 4.3. Listing installed packages using a double-quoted glob expression

To list all installed packages that begin with “krb” followed by exactly one character and a hyphen, type:

```
~]# yum list installed "krb?-*"
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
krb5-libs.x86_64              1.9-7.fc15              @fedora
```

yum list available

Lists all available packages in all enabled repositories.

Example 4.4. Listing available packages using a single glob expression with escaped wildcard characters

To list all available packages with names that contain “gstreamer” and then “plugin”, run the following command:

```
~]# yum list available gstreamer\*plugin\*
Loaded plugins: langpacks, presto, refresh-packagekit
Available Packages
gstreamer-plugin-crystalhd.x86_64               3.5.1-1.fc14       fedora
gstreamer-plugins-bad-free.x86_64               0.10.22-1.fc15     updates
gstreamer-plugins-bad-free-devel.x86_64         0.10.22-1.fc15     updates
gstreamer-plugins-bad-free-devel-docs.x86_64    0.10.22-1.fc15     updates
gstreamer-plugins-bad-free-extras.x86_64        0.10.22-1.fc15     updates
gstreamer-plugins-base.x86_64                   0.10.33-1.fc15     updates
gstreamer-plugins-base-devel.x86_64             0.10.33-1.fc15     updates
gstreamer-plugins-base-devel-docs.noarch        0.10.33-1.fc15     updates
gstreamer-plugins-base-tools.x86_64             0.10.33-1.fc15     updates
gstreamer-plugins-espeak.x86_64                 0.3.3-3.fc15       fedora
gstreamer-plugins-fc.x86_64                     0.2-2.fc15         fedora
gstreamer-plugins-good.x86_64                   0.10.29-1.fc15     updates
gstreamer-plugins-good-devel-docs.noarch        0.10.29-1.fc15     updates
```

yum grouplist

Lists all package groups.

Example 4.5. Listing all package groups

```
~]# yum grouplist
Loaded plugins: langpacks, presto, refresh-packagekit
Setting up Group Process
Installed Groups:
   Administration Tools
   Design Suite
   Dial-up Networking Support
   Fonts
   GNOME Desktop Environment
```

```
[output truncated]
```

yum repolist

Lists the repository ID, name, and number of packages it provides for each *enabled* repository.

Example 4.6. Listing enabled repositories

```
~]# yum repolist
Loaded plugins: langpacks, presto, refresh-packagekit
repo id                      repo name                                  status
fedora                       Fedora 15 - i386                           19,365
updates                      Fedora 15 - i386 - Updates                 3,848
repolist: 23,213
```

4.2.3. Displaying Package Information

To display information about one or more packages (glob expressions are valid here as well), use the following command:

```
yum info package_name…
```

For example, to display information about the *abrt* package, type:

```
~]# yum info abrt
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
Name        : abrt
Arch        : x86_64
Version     : 2.0.1
Release     : 2.fc15
Size        : 806 k
Repo        : installed
From repo   : fedora
Summary     : Automatic bug detection and reporting tool
URL         : https://fedorahosted.org/abrt/
License     : GPLv2+
Description : abrt is a tool to help users to detect defects in applications and
            : to create a bug report with all informations needed by maintainer
            : to fix it. It uses plugin system to extend its functionality.
```

The **yum info *package_name*** command is similar to the **rpm -q --info *package_name*** command, but provides as additional information the ID of the Yum repository the RPM package is found in (look for the **From repo:** line in the output).

You can also query the Yum database for alternative and useful information about a package by using the following command:

```
yumdb info package_name
```

This command provides additional information about a package, including the checksum of the package (and algorithm used to produce it, such as SHA-256), the command given on the command line that was invoked to install the package (if any), and the reason that the package is installed on the system (where **user** indicates it was installed by the user, and **dep** means it was brought in as a dependency). For example, to display additional information about the *yum* package, type:

```
~]# yumdb info yum
Loaded plugins: langpacks, presto, refresh-packagekit
yum-3.2.29-4.fc15.noarch
     checksum_data = 249f21fb43c41381c8c9b0cd98d2ea5fa0aa165e81ed2009cfda74c05af67246
     checksum_type = sha256
     from_repo = fedora
     from_repo_revision = 1304429533
     from_repo_timestamp = 1304442346
     installed_by = 0
     reason = user
     releasever = $releasever
```

For more information on the **yumdb** command, refer to the **yumdb**(8) manual page.

4.2.4. Installing Packages

Yum allows you to install both a single package and multiple packages, as well as a package group of your choice.

Installing Individual Packages

To install a single package and all of its non-installed dependencies, enter a command in the following form:

```
yum install package_name
```

You can also install multiple packages simultaneously by appending their names as arguments:

```
yum install package_name package_name…
```

If you are installing packages on a *multilib* system, such as an AMD64 or Intel64 machine, you can specify the architecture of the package (as long as it is available in an enabled repository) by appending `.arch` to the package name. For example, to install the *sqlite2* package for `i586`, type:

```
~]# yum install sqlite2.i586
```

You can use glob expressions to quickly install multiple similarly-named packages:

```
~]# yum install audacious-plugins-\*
```

In addition to package names and glob expressions, you can also provide file names to **yum install**. If you know the name of the binary you want to install, but not its package name, you can give **yum install** the path name:

```
~]# yum install /usr/sbin/named
```

yum then searches through its package lists, finds the package which provides **/usr/sbin/named**, if any, and prompts you as to whether you want to install it.



Finding which package owns a file

If you know you want to install the package that contains the **named** binary, but you do not know in which **bin** or **sbin** directory is the file installed, use the **yum provides** command with a glob expression:

```
~]# yum provides "*bin/named"
Loaded plugins: langpacks, presto, refresh-packagekit
32:bind-9.8.0-3.P1.fc15.i686 : The Berkeley Internet Name Domain (BIND) DNS
                             : (Domain Name System) server
Repo        : fedora
Matched from:
Filename    : /usr/sbin/named
```

yum provides "*/*file_name*" is a common and useful trick to find the packages that contain *file_name*.

Installing a Package Group

A package group is similar to a package: it is not useful by itself, but installing one pulls a group of dependent packages that serve a common purpose. A package group has a name and a *groupid*. The **yum grouplist -v** command lists the names of all package groups, and, next to each of them, their groupid in parentheses. The groupid is always the term in the last pair of parentheses, such as **kde-desktop** in the following example:

```
~]# yum -v grouplist kde\*
Not loading "blacklist" plugin, as it is disabled
Loading "langpacks" plugin
Loading "presto" plugin
Loading "refresh-packagekit" plugin
Not loading "whiteout" plugin, as it is disabled
Adding en_US to language list
Config time: 0.900
Yum Version: 3.2.29
Setting up Group Process
rpmdb time: 0.002
group time: 0.995
Available Groups:
   KDE Software Compilation (kde-desktop)
   KDE Software Development (kde-software-development)
Done
```

You can install a package group by passing its full group name (without the groupid part) to **groupinstall**:

```
yum groupinstall group_name
```

You can also install by groupid:

```
yum groupinstall groupid
```

You can even pass the groupid (or quoted name) to the **install** command if you prepend it with an @-symbol (which tells **yum** that you want to perform a **groupinstall**):

```
yum install @group
```

For example, the following are alternative but equivalent ways of installing the **KDE Desktop** group:

```
~]# yum groupinstall "KDE Desktop"
~]# yum groupinstall kde-desktop
~]# yum install @kde-desktop
```

4.2.5. Removing Packages

Similarly to package installation, Yum allows you to uninstall (remove in **RPM** and Yum terminology) both individual packages and a package group.

Removing Individual Packages

To uninstall a particular package, as well as any packages that depend on it, run the following command as `root`:

```
yum remove package_name…
```

As when you install multiple packages, you can remove several at once by adding more package names to the command. For example, to remove *totem*, *rhythmbox*, and *sound-juicer*, type the following at a shell prompt:

```
~]# yum remove totem rhythmbox sound-juicer
```

Similar to **install**, **remove** can take these arguments:

- package names
- glob expressions
- file lists
- package provides



Removing a package when other packages depend on it

Yum is not able to remove a package without also removing packages which depend on it. This type of operation can only be performed by **RPM**, is not advised, and can potentially leave your system in a non-functioning state or cause applications to misbehave and/or crash. For further information, refer to *Section B.2.4, "Uninstalling"* in the **RPM** chapter.

Removing a Package Group

You can remove a package group using syntax congruent with the **install** syntax:

```
yum groupremove group
```

```
yum remove @group
```

The following are alternative but equivalent ways of removing the **KDE Desktop** group:

```
~]# yum groupremove "KDE Desktop"
~]# yum groupremove kde-desktop
~]# yum remove @kde-desktop
```



Intelligent package group removal

When you tell **yum** to remove a package group, it will remove every package in that group, even if those packages are members of other package groups or dependencies of other installed packages. However, you can instruct **yum** to remove only those packages which are not required by any other packages or groups by adding the **groupremove_leaf_only=1** directive to the **[main]** section of the **/etc/yum.conf** configuration file. For more information on this directive, refer to *Section 4.3.1, "Setting [main] Options"*.

4.2.6. Working with Transaction History

The **yum history** command allows users to review information about a timeline of Yum transactions, the dates and times on when they occurred, the number of packages affected, whether transactions succeeded or were aborted, and if the RPM database was changed between transactions. Additionally, this command can be used to undo or redo certain transactions.

Listing Transactions

To display a list of twenty most recent transactions, as `root`, either run **yum history** with no additional arguments, or type the following at a shell prompt:

```
yum history list
```

To display all transactions, add the **all** keyword:

```
yum history list all
```

To display only transactions in a given range, use the command in the following form:

```
yum history list start_id..end_id
```

You can also list only transactions regarding a particular package or packages. To do so, use the command with a package name or a glob expression:

```
yum history list glob_expression…
```

For example, the list of first five transactions may look as follows:

```
~]# yum history list 1..5
Loaded plugins: langpacks, presto, refresh-packagekit
```

```
ID     | Login user               | Date and time    | Action(s)      | Altered
-------------------------------------------------------------------------------
     5 | Jaromir ... <jhradilek>  | 2011-07-29 15:33 | Install        |    1
     4 | Jaromir ... <jhradilek>  | 2011-07-21 15:10 | Install        |    1
     3 | Jaromir ... <jhradilek>  | 2011-07-16 15:27 | I, U           |   73
     2 | System <unset>           | 2011-07-16 15:19 | Update         |    1
     1 | System <unset>           | 2011-07-16 14:38 | Install        | 1106
history list
```

All forms of the **yum history list** command produce tabular output with each row consisting of the following columns:

- **ID** — an integer value that identifies a particular transaction.
- **Login user** — the name of the user whose login session was used to initiate a transaction. This information is typically presented in the ***Full Name <username>*** form. For transactions that were not issued by a user (such as an automatic system update), **System <unset>** is used instead.
- **Date and time** — the date and time when a transaction was issued.
- **Action(s)** — a list of actions that were performed during a transaction as described in *Table 4.1, "Possible values of the Action(s) field"*.
- **Altered** — the number of packages that were affected by a transaction, possibly followed by additional information as described in *Table 4.2, "Possible values of the Altered field"*.

Table 4.1. Possible values of the Action(s) field

Action	Abbreviation	Description
Downgrade	**D**	At least one package has been downgraded to an older version.
Erase	**E**	At least one package has been removed.
Install	**I**	At least one new package has been installed.
Obsoleting	**O**	At least one package has been marked as obsolete.
Reinstall	**R**	At least one package has been reinstalled.
Update	**U**	At least one package has been updated to a newer version.

Table 4.2. Possible values of the Altered field

Symbol	Description
<	Before the transaction finished, the **rpmdb** database was changed outside Yum.
>	After the transaction finished, the **rpmdb** database was changed outside Yum.
*****	The transaction failed to finish.
#	The transaction finished successfully, but **yum** returned a non-zero exit code.
E	The transaction finished successfully, but an error or a warning was displayed.
P	The transaction finished successfully, but problems already existed in the **rpmdb** database.
s	The transaction finished successfully, but the **--skip-broken** command line option was used and certain packages were skipped.

Yum also allows you to display a summary of all past transactions. To do so, run the command in the following form as `root`:

```
yum history summary
```

To display only transactions in a given range, type:

```
yum history summary start_id..end_id
```

Similarly to the **yum history list** command, you can also display a summary of transactions regarding a certain package or packages by supplying a package name or a glob expression:

```
yum history summary glob_expression…
```

For instance, a summary of the transaction history displayed above would look like the following:

```
~]# yum history summary 1..5
Loaded plugins: langpacks, presto, refresh-packagekit
Login user                | Time                | Action(s)        | Altered
-------------------------------------------------------------------------------
Jaromir ... <jhradilek>   | Last day            | Install          |        1
Jaromir ... <jhradilek>   | Last week           | Install          |        1
Jaromir ... <jhradilek>   | Last 2 weeks        | I, U             |       73
System <unset>            | Last 2 weeks        | I, U             |     1107
history summary
```

All forms of the **yum history summary** command produce simplified tabular output similar to the output of **yum history list**.

As shown above, both **yum history list** and **yum history summary** are oriented towards transactions, and although they allow you to display only transactions related to a given package or packages, they lack important details, such as package versions. To list transactions from the perspective of a package, run the following command as `root`:

```
yum history package-list glob_expression…
```

For example, to trace the history of *subscription-manager* and related packages, type the following at a shell prompt:

```
~]# yum history package-list subscription-manager\*
Loaded plugins: langpacks, presto, refresh-packagekit
ID     | Action(s)      | Package
-------------------------------------------------------------------------------
     3 | Updated        | subscription-manager-0.95.11-1.el6.x86_64
     3 | Update         |                      0.95.17-1.el6_1.x86_64
     3 | Updated        | subscription-manager-firstboot-0.95.11-1.el6.x86_64
     3 | Update         |                                0.95.17-1.el6_1.x86_64
     3 | Updated        | subscription-manager-gnome-0.95.11-1.el6.x86_64
     3 | Update         |                            0.95.17-1.el6_1.x86_64
     1 | Install        | subscription-manager-0.95.11-1.el6.x86_64
     1 | Install        | subscription-manager-firstboot-0.95.11-1.el6.x86_64
     1 | Install        | subscription-manager-gnome-0.95.11-1.el6.x86_64
history package-list
```

In this example, three packages were installed during the initial system installation: *subscription-manager*, *subscription-manager-firstboot*, and *subscription-manager-gnome*. In the third transaction, all these packages were updated from version 0.95.11 to version 0.95.17.

Examining Transactions

To display the summary of a single transaction, as `root`, use the **yum history summary** command in the following form:

```
yum history summary id
```

To examine a particular transaction or transactions in more detail, run the following command as `root`:

```
yum history info id…
```

The *id* argument is optional and when you omit it, **yum** automatically uses the last transaction. Note that when specifying more than one transaction, you can also use a range:

```
yum history info start_id..end_id
```

The following is sample output for two transactions, each installing one new package:

```
~]# yum history info 4..5
Loaded plugins: langpacks, presto, refresh-packagekit
Transaction ID : 4..5
Begin time     : Thu Jul 21 15:10:46 2011
Begin rpmdb    : 1107:0c67c32219c199f92ed8da7572b4c6df64eacd3a
End time       :            15:33:15 2011 (22 minutes)
End rpmdb      : 1109:1171025bd9b6b5f8db30d063598f590f1c1f3242
User           : Jaromir Hradilek <jhradilek>
Return-Code    : Success
Command Line   : install screen
Command Line   : install yum-plugin-fs-snapshot
Transaction performed with:
    Installed     rpm-4.8.0-16.el6.x86_64
    Installed     yum-3.2.29-17.el6.noarch
    Installed     yum-metadata-parser-1.1.2-16.el6.x86_64
Packages Altered:
    Install screen-4.0.3-16.el6.x86_64
    Install yum-plugin-fs-snapshot-1.1.30-6.el6.noarch
history info
```

You can also view additional information, such as what configuration options were used at the time of the transaction, or from what repository and why were certain packages installed. To determine what additional information is available for a certain transaction, type the following at a shell prompt as `root`:

```
yum history addon-info id
```

Similarly to **yum history info**, when no *id* is provided, **yum** automatically uses the latest transaction. Another way to refer to the latest transaction is to use the **last** keyword:

```
yum history addon-info last
```

For instance, for the first transaction in the previous example, the **yum history addon-info** command would provide the following output:

```
~]# yum history addon-info 4
Loaded plugins: langpacks, presto, refresh-packagekit
Transaction ID: 4
Available additional history information:
  config-main
  config-repos
```

```
  saved_tx

history addon-info
```

In this example, three types of information are available:

- **config-main** — global Yum options that were in use during the transaction. Refer to *Section 4.3.1, "Setting [main] Options"* for information on how to change global options.
- **config-repos** — options for individual Yum repositories. Refer to *Section 4.3.2, "Setting [repository] Options"* for information on how to change options for individual repositories.
- **saved_tx** — the data that can be used by the **yum load-transaction** command in order to repeat the transaction on another machine (see below).

To display selected type of additional information, run the following command as `root`:

```
yum history addon-info id information
```

Reverting and Repeating Transactions

Apart from reviewing the transaction history, the **yum history** command provides means to revert or repeat a selected transaction. To revert a transaction, type the following at a shell prompt as `root`:

```
yum history undo id
```

To repeat a particular transaction, as `root`, run the following command:

```
yum history redo id
```

Both commands also accept the **last** keyword to undo or repeat the latest transaction.

Note that both **yum history undo** and **yum history redo** commands merely revert or repeat the steps that were performed during a transaction: if the transaction installed a new package, the **yum history undo** command will uninstall it, and vice versa. If possible, this command will also attempt to downgrade all updated packages to their previous version, but these older packages may no longer be available. If you need to be able to restore the system to the state before an update, consider using the **fs-snapshot** plug-in described in *Section 4.4.3, "Plug-in Descriptions"*.

When managing several identical systems, Yum also allows you to perform a transaction on one of them, store the transaction details in a file, and after a period of testing, repeat the same transaction on the remaining systems as well. To store the transaction details to a file, type the following at a shell prompt as `root`:

```
yum -q history addon-info id saved_tx > file_name
```

Once you copy this file to the target system, you can repeat the transaction by using the following command as `root`:

```
yum load-transaction file_name
```

Note, however that the **rpmdb** version stored in the file must by identical to the version on the target system. You can verify the **rpmdb** version by using the **yum version nogroups** command.

Starting New Transaction History

Yum stores the transaction history in a single SQLite database file. To start new transaction history, run the following command as `root`:

```
yum history new
```

This will create a new, empty database file in the **/var/lib/yum/history/** directory. The old transaction history will be kept, but will not be accessible as long as a newer database file is present in the directory.

4.3. Configuring Yum and Yum Repositories

The configuration file for **yum** and related utilities is located at **/etc/yum.conf**. This file contains one mandatory **[main]** section, which allows you to set Yum options that have global effect, and may also contain one or more **[*repository*]** sections, which allow you to set repository-specific options. However, best practice is to define individual repositories in new or existing **.repo** files in the **/etc/yum.repos.d/**directory. The values you define in the **[main]** section of the **/etc/yum.conf** file may override values set in individual **[*repository*]** sections.

This section shows you how to:

- set global Yum options by editing the **[main]** section of the **/etc/yum.conf** configuration file;
- set options for individual repositories by editing the **[*repository*]** sections in **/etc/yum.conf** and **.repo** files in the **/etc/yum.repos.d/** directory;
- use Yum variables in **/etc/yum.conf** and files in the **/etc/yum.repos.d/** directory so that dynamic version and architecture values are handled correctly;
- add, enable, and disable Yum repositories on the command line; and,
- set up your own custom Yum repository.

4.3.1. Setting [main] Options

The **/etc/yum.conf** configuration file contains exactly one **[main]** section, and while some of the key-value pairs in this section affect how **yum** operates, others affect how Yum treats repositories. You can add many additional options under the **[main]** section heading in **/etc/yum.conf**.

A sample **/etc/yum.conf** configuration file can look like this:

```
[main]
cachedir=/var/cache/yum/$basearch/$releasever
keepcache=0
debuglevel=2
logfile=/var/log/yum.log
exactarch=1
obsoletes=1
gpgcheck=1
plugins=1
installonly_limit=3

[comments abridged]

# PUT YOUR REPOS HERE OR IN separate files named file.repo
```

```
# in /etc/yum.repos.d
```

The following are the most commonly-used options in the **[main]** section:

assumeyes=*value*
…where *value* is one of:

0 — **yum** should prompt for confirmation of critical actions it performs. This is the default.

1 — Do not prompt for confirmation of critical **yum** actions. If **assumeyes=1** is set, **yum** behaves in the same way that the command line option **-y** does.

cachedir=*directory*
…where *directory* is an absolute path to the directory where Yum should store its cache and database files. By default, Yum's cache directory is **/var/cache/yum/$basearch/$releasever**.

Refer to *Section 4.3.3, "Using Yum Variables"* for descriptions of the `$basearch` and `$releasever` Yum variables.

debuglevel=*value*
…where *value* is an integer between **1** and **10**. Setting a higher **debuglevel** value causes **yum** to display more detailed debugging output. **debuglevel=0** disables debugging output, while **debuglevel=2** is the default.

exactarch=*value*
…where *value* is one of:

0 — Do not take into account the exact architecture when updating packages.

1 — Consider the exact architecture when updating packages. With this setting, **yum** will not install an i686 package to update an i386 package already installed on the system. This is the default.

exclude=*package_name* [*more_package_names*]
This option allows you to exclude packages by keyword during installation/updates. Listing multiple packages for exclusion can be accomplished by quoting a space-delimited list of packages. Shell globs using wildcards (for example, ***** and **?**) are allowed.

gpgcheck=*value*
…where *value* is one of:

0 — Disable GPG signature-checking on packages in all repositories, including local package installation.

1 — Enable GPG signature-checking on all packages in all repositories, including local package installation. **gpgcheck=1** is the default, and thus all packages' signatures are checked.

If this option is set in the **[main]** section of the **/etc/yum.conf** file, it sets the GPG-checking rule for all repositories. However, you can also set **gpgcheck=*value*** for individual repositories instead; that is, you can enable GPG-checking on one repository while disabling it on another. Setting **gpgcheck=*value*** for an individual repository in its corresponding **.repo** file overrides the default if it is present in **/etc/yum.conf**.

For more information on GPG signature-checking, refer to *Section B.3, "Checking a Package's Signature"*.

groupremove_leaf_only=*value*
…where *value* is one of:

0 — **yum** should *not* check the dependencies of each package when removing a package group. With this setting, **yum** removes all packages in a package group, regardless of whether those packages are required by other packages or groups. **groupremove_leaf_only=0** is the default.

1 — **yum** should check the dependencies of each package when removing a package group, and remove only those packages which are not not required by any other package or group.

For more information on removing packages, refer to *Intelligent package group removal*.

installonlypkgs=*space separated list of packages*
Here you can provide a space-separated list of packages which **yum** can *install*, but will never *update*. Refer to the **yum.conf**(5) manual page for the list of packages which are install-only by default.

If you add the **installonlypkgs** directive to **/etc/yum.conf**, you should ensure that you list *all* of the packages that should be install-only, including any of those listed under the **installonlypkgs** section of **yum.conf**(5). In particular, kernel packages should always be listed in **installonlypkgs** (as they are by default), and **installonly_limit** should always be set to a value greater than **2** so that a backup kernel is always available in case the default one fails to boot.

installonly_limit=*value*
…where *value* is an integer representing the maximum number of versions that can be installed simultaneously for any single package listed in the **installonlypkgs** directive.

The defaults for the **installonlypkgs** directive include several different kernel packages, so be aware that changing the value of **installonly_limit** will also affect the maximum number of installed versions of any single kernel package. The default value listed in **/etc/yum.conf** is **installonly_limit=3**, and it is not recommended to decrease this value, particularly below **2**.

keepcache=*value*
…where *value* is one of:

0 — Do not retain the cache of headers and packages after a successful installation. This is the default.

1 — Retain the cache after a successful installation.

logfile=*file_name*
…where *file_name* is an absolute path to the file in which **yum** should write its logging output. By default, **yum** logs to **/var/log/yum.log**.

multilib_policy=*value*
…where *value* is one of:

best — install the best-choice architecture for this system. For example, setting **multilib_policy=best** on an AMD64 system causes **yum** to install 64-bit versions of all packages.

all — always install every possible architecture for every package. For example, with **multilib_policy** set to **all** on an AMD64 system, **yum** would install both the i586 and AMD64 versions of a package, if both were available.

obsoletes=*value*
…where *value* is one of:

0 — Disable **yum**'s obsoletes processing logic when performing updates.

1 — Enable **yum**'s obsoletes processing logic when performing updates. When one package declares in its spec file that it *obsoletes* another package, the latter package will be replaced by the former package when the former package is installed. Obsoletes are declared, for example, when a package is renamed. **obsoletes=1** the default.

plugins=*value*
…where *value* is one of:

0 — Disable all Yum plug-ins globally.



Disabling all plug-ins is not advised

Disabling all plug-ins is not advised because certain plug-ins provide important **Yum** services. Disabling plug-ins globally is provided as a convenience option, and is generally only recommended when diagnosing a potential problem with **Yum**.

1 — Enable all Yum plug-ins globally. With **plugins=1**, you can still disable a specific Yum plug-in by setting **enabled=0** in that plug-in's configuration file.

For more information about various Yum plug-ins, refer to *Section 4.4, "Yum Plug-ins"*. For further information on controlling plug-ins, see *Section 4.4.1, "Enabling, Configuring, and Disabling Yum Plug-ins"*.

reposdir=*directory*
…where *directory* is an absolute path to the directory where **.repo** files are located. All **.repo** files contain repository information (similar to the **[*repository*]** sections of **/etc/yum.conf**). **yum** collects all repository information from **.repo** files and the **[*repository*]** section of the **/etc/yum.conf** file to create a master list of repositories to use for transactions. If **reposdir** is not set, **yum** uses the default directory **/etc/yum.repos.d/**.

retries=*value*
…where *value* is an integer **0** or greater. This value sets the number of times **yum** should attempt to retrieve a file before returning an error. Setting this to **0** makes **yum** retry forever. The default value is **10**.

For a complete list of available **[main]** options, refer to the **[main] OPTIONS** section of the **yum.conf**(5) manual page.

4.3.2. Setting [repository] Options

The **[*repository*]** sections, where *repository* is a unique repository ID such as **my_personal_repo** (spaces are not permitted), allow you to define individual Yum repositories.

The following is a bare-minimum example of the form a **[*repository*]** section takes:

```
[repository]
name=repository_name
baseurl=repository_url
```

Every **[*repository*]** section must contain the following directives:

name=*repository_name*
…where *repository_name* is a human-readable string describing the repository.

baseurl=*repository_url*
…where *repository_url* is a URL to the directory where the repodata directory of a repository is located:

- If the repository is available over HTTP, use: **http://path/to/repo**
- If the repository is available over FTP, use: **ftp://path/to/repo**
- If the repository is local to the machine, use: **file:///path/to/local/repo**
- If a specific online repository requires basic HTTP authentication, you can specify your username and password by prepending it to the URL as ***username*:*password*@*link***. For example, if a repository on http://www.example.com/repo/ requires a username of "user" and a password of "password", then the **baseurl** link could be specified as **http://user:password@www.example.com/repo/**.

Usually this URL is an HTTP link, such as:

```
baseurl=http://path/to/repo/releases/$releasever/server/$basearch/os/
```

Note that Yum always expands the `$releasever`, `$arch`, and `$basearch` variables in URLs. For more information about Yum variables, refer to *Section 4.3.3, "Using Yum Variables"*.

Another useful **[*repository*]** directive is the following:

enabled=*value*
…where *value* is one of:

0 — Do not include this repository as a package source when performing updates and installs. This is an easy way of quickly turning repositories on and off, which is useful when you desire a single package from a repository that you do not want to enable for updates or installs.

1 — Include this repository as a package source.

Turning repositories on and off can also be performed by passing either the **--enablerepo=*repo_name*** or **--disablerepo=*repo_name*** option to **yum**, or through the **Add/Remove Software** window of the **PackageKit** utility.

Many more **[*repository*]** options exist. For a complete list, refer to the **[repository] OPTIONS** section of the **yum.conf**(5) manual page.

4.3.3. Using Yum Variables

You can use and reference the following built-in variables in **yum** commands and in all Yum configuration files (that is, **/etc/yum.conf** and all **.repo** files in the **/etc/yum.repos.d/** directory):

`$releasever`
You can use this variable to reference the release version of Fedora. Yum obtains the value of `$releasever` from the **distroverpkg=*value*** line in the **/etc/yum.conf** configuration file. If there is no such line in **/etc/yum.conf**, then **yum** infers the correct value by deriving the version number from the *redhat-release* package.

`$arch`
: You can use this variable to refer to the system's CPU architecture as returned when calling Python's `os.uname()` function. Valid values for `$arch` include: **`i586`**, **`i686`** and **`x86_64`**.

`$basearch`
: You can use `$basearch` to reference the base architecture of the system. For example, i686 and i586 machines both have a base architecture of **`i386`**, and AMD64 and Intel64 machines have a base architecture of **`x86_64`**.

`$YUM0-9`
: These ten variables are each replaced with the value of any shell environment variables with the same name. If one of these variables is referenced (in **`/etc/yum.conf`** for example) and a shell environment variable with the same name does not exist, then the configuration file variable is not replaced.

To define a custom variable or to override the value of an existing one, create a file with the same name as the variable (without the "**`$`**" sign) in the **`/etc/yum/vars/`** directory, and add the desired value on its first line.

For example, repository descriptions often include the operating system name. To define a new variable called `$osname`, create a new file with "Fedora" on the first line and save it as **`/etc/yum/vars/osname`**:

```
~]# echo "Fedora" > /etc/yum/vars/osname
```

Instead of "Fedora 17", you can now use the following in the **`.repo`** files:

```
name=$osname $releasever
```

4.3.4. Viewing the Current Configuration

To display the current values of global Yum options (that is, the options specified in the **`[main]`** section of the **`/etc/yum.conf`** file), run the **`yum-config-manager`** with no command line options:

```
yum-config-manager
```

To list the content of a different configuration section or sections, use the command in the following form:

```
yum-config-manager section…
```

You can also use a glob expression to display the configuration of all matching sections:

```
yum-config-manager glob_expression…
```

For example, to list all configuration options and their corresponding values, type the following at a shell prompt:

```
~]$ yum-config-manager main \*
Loaded plugins: langpacks, presto, refresh-packagekit
================================== main ==================================
[main]
```

```
alwaysprompt = True
assumeyes = False
bandwith = 0
bugtracker_url = https://bugzilla.redhat.com/enter_bug.cgi?product=Red%20Hat%20Enterprise
%20Linux%206&component=yum
cache = 0
[output truncated]
```

4.3.5. Adding, Enabling, and Disabling a Yum Repository

Section 4.3.2, "Setting [repository] Options" described various options you can use to define a Yum repository. This section explains how to add, enable, and disable a repository by using the **yum-config-manager** command.

Adding a Yum Repository

To define a new repository, you can either add a **[*repository*]** section to the **/etc/yum.conf** file, or to a **.repo** file in the **/etc/yum.repos.d/** directory. All files with the **.repo** file extension in this directory are read by **yum**, and best practice is to define your repositories here instead of in **/etc/yum.conf**.



Be careful when using untrusted software sources

Obtaining and installing software packages from unverified or untrusted software sources constitutes a potential security risk, and could lead to security, stability, compatibility maintainability issues.

Yum repositories commonly provide their own **.repo** file. To add such a repository to your system and enable it, run the following command as `root`:

```
yum-config-manager --add-repo repository_url
```

…where *repository_url* is a link to the **.repo** file. For example, to add a repository located at http://www.example.com/example.repo, type the following at a shell prompt:

```
~]# yum-config-manager --add-repo http://www.example.com/example.repo
Loaded plugins: langpacks, presto, refresh-packagekit
adding repo from: http://www.example.com/example.repo
grabbing file http://www.example.com/example.repo to /etc/yum.repos.d/example.repo
example.repo                                             |  413 B     00:00
repo saved to /etc/yum.repos.d/example.repo
```

Enabling a Yum Repository

To enable a particular repository or repositories, type the following at a shell prompt as `root`:

```
yum-config-manager --enable repository…
```

…where *repository* is the unique repository ID (use **yum repolist all** to list available repository IDs). Alternatively, you can use a glob expression to enable all matching repositories:

```
yum-config-manager --enable glob_expression…
```

For example, to disable repositories defined in the **[example]**, **[example-debuginfo]**, and **[example-source]**sections, type:

```
~]# yum-config-manager --enable example\*
Loaded plugins: langpacks, presto, refresh-packagekit
============================== repo: example ===============================
[example]
bandwidth = 0
base_persistdir = /var/lib/yum/repos/x86_64/6Server
baseurl = http://www.example.com/repo/6Server/x86_64/
cache = 0
cachedir = /var/cache/yum/x86_64/6Server/example
[output truncated]
```

When successful, the **yum-config-manager --enable** command displays the current repository configuration.

Disabling a Yum Repository

To disable a Yum repository, run the following command as `root`:

```
yum-config-manager --disable repository…
```

…where *repository* is the unique repository ID (use **yum repolist all** to list available repository IDs). Similarly to **yum-config-manager --enable**, you can use a glob expression to disable all matching repositories at the same time:

```
yum-config-manager --disable glob_expression…
```

When successful, the **yum-config-manager --disable** command displays the current configuration.

4.3.6. Creating a Yum Repository

To set up a Yum repository, follow these steps:

1. Install the *createrepo* package:

```
~]# yum install createrepo
```

2. Copy all of the packages into one directory, such as **/mnt/local_repo/**.

3. Run the **createrepo --database** command on that directory:

```
~]# createrepo --database /mnt/local_repo
```

This creates the necessary metadata for your Yum repository, as well as the **sqlite** database for speeding up **yum** operations.

4.4. Yum Plug-ins

Yum provides plug-ins that extend and enhance its operations. Certain plug-ins are installed by default. Yum always informs you which plug-ins, if any, are loaded and active whenever you call any **yum** command. For example:

```
~]# yum info yum
Loaded plugins: langpacks, presto, refresh-packagekit
[output truncated]
```

Note that the plug-in names which follow **Loaded plugins** are the names you can provide to the **--disableplugins=*plugin_name*** option.

4.4.1. Enabling, Configuring, and Disabling Yum Plug-ins

To enable Yum plug-ins, ensure that a line beginning with **plugins=** is present in the **[main]** section of **/etc/yum.conf**, and that its value is set to **1**:

```
plugins=1
```

You can disable all plug-ins by changing this line to **plugins=0**.



Disabling all plug-ins is not advised

Disabling all plug-ins is not advised because certain plug-ins provide important **Yum** services. Disabling plug-ins globally is provided as a convenience option, and is generally only recommended when diagnosing a potential problem with **Yum**.

Every installed plug-in has its own configuration file in the **/etc/yum/pluginconf.d/** directory. You can set plug-in specific options in these files. For example, here is the **refresh-packagekit** plug-in's **refresh-packagekit.conf** configuration file:

```
[main]
enabled=1
```

Plug-in configuration files always contain a **[main]** section (similar to Yum's **/etc/yum.conf** file) in which there is (or you can place if it is missing) an **enabled=** option that controls whether the plug-in is enabled when you run **yum** commands.

If you disable all plug-ins by setting **enabled=0** in **/etc/yum.conf**, then all plug-ins are disabled regardless of whether they are enabled in their individual configuration files.

If you merely want to disable all Yum plug-ins for a single **yum** command, use the **--noplugins** option.

If you want to disable one or more Yum plug-ins for a single **yum** command, add the **--disableplugin=*plugin_name*** option to the command. For example, to disable the **presto** plug-in while updating a system, type:

```
~]# yum update --disableplugin=presto
```

The plug-in names you provide to the **--disableplugin=** option are the same names listed after the **Loaded plugins** line in the output of any **yum** command. You can disable multiple plug-ins by

separating their names with commas. In addition, you can match multiple plug-in names or shorten long ones by using glob expressions:

```
~]# yum update --disableplugin=presto,refresh-pack*
```

4.4.2. Installing Additional Yum Plug-ins

Yum plug-ins usually adhere to the **yum-plugin-*plugin_name*** package-naming convention, but not always: the package which provides the **presto** plug-in is named **yum-presto**, for example. You can install a Yum plug-in in the same way you install other packages. For instance, to install the **security** plug-in, type the following at a shell prompt:

```
~]# yum install yum-plugin-security
```

4.4.3. Plug-in Descriptions

The following list provides descriptions of a few useful Yum plug-ins:

fs-snapshot (*yum-plugin-fs-snapshot*)

The **fs-snapshot** plug-in extends Yum to create a snapshot of a file system before proceeding with a transaction such as a system update or package removal. When a user decides that the changes made by the transaction are unwanted, this mechanism allows the user to roll back to the changes that are stored in a snapshot.

In order for the plug-in to work, the root file system (that is, `/`) must be on an `LVM` (Logical Volume Manager) or `Btrfs` volume. To use the **fs-snapshot** plug-in on an LVM volume, take the following steps:

1. Make sure that the volume group with the root file system has enough free extents. The required size is a function of the amount of changes to the original logical volume that is expected during the life of the snapshot. The reasonable default is 50–80 % of the original logical volume size.

   To display detailed information about a particular volume group, run the **vgdisplay** command in the following form as `root`:

   ```
   vgdisplay volume_group
   ```

   The number of free extents is listed on the **Free PE / Size** line.

2. If the volume group with the root file system does not have enough free extents, add a new physical volume:

   a. As `root`, run the **pvcreate** command in the following form to initialize a physical volume for use with the Logical Volume Manager:

   ```
   pvcreate device
   ```

   b. Use the **vgextend** command in the following form as `root` to add the physical volume to the volume group:

   ```
   vgextend volume_group physical_volume
   ```

3. Edit the configuration file located in **/etc/yum/pluginconf.d/fs-snapshot.conf**, and make the following changes to the **[lvm]** section:

   a. Change the value of the **enabled** option to **1**:

   ```
   enabled = 1
   ```

   b. Remove the hash sign (that is, **#**) from the beginning of the **lvcreate_size_args** line, and adjust the number of logical extents to be allocated for a snapshot. For example, to allocate 80 % of the size of the original logical volume, use:

   ```
   lvcreate_size_args = -l 80%ORIGIN
   ```

   Refer to *Table 4.3, "Supported **fs-snapshot.conf** directives"* for a complete list of available configuration options.

4. Run the desired **yum** command, and make sure **fs-snapshot** is included in the list of loaded plug-ins (the **Loaded plugins** line) before you confirm the changes and proceed with the transaction. The **fs-snapshot** plug-in displays a line in the following form for each affected logical volume:

   ```
   fs-snapshot: snapshotting file_system (/
   dev/volume_group/logical_volume): logical_volume_yum_timestamp
   ```

5. Verify that the system is working as expected:

   If you decide to keep the changes, remove the snapshot by running the **lvremove** command as `root`:

   ```
   lvremove /dev/volume_group/logical_volume_yum_timestamp
   ```

   If you decide to revert the changes and restore the file system to a state that is saved in a snapshot, take the following steps:

   a. As `root`, run the command in the following form to merge a snapshot into its original logical volume:

   ```
   lvconvert --merge /dev/volume_group/logical_volume_yum_timestamp
   ```

   The **lvconvert** command will inform you that a restart is required in order for the changes to take effect.

   b. Restart the system as instructed. You can do so by typing the following at a shell prompt as `root`:

   ```
   reboot
   ```

To use the **fs-snapshot** plug-in on a Btrfs file system, take the following steps:

1. Run the desired **yum** command, and make sure **fs-snapshot** is included in the list of loaded plug-ins (the **Loaded plugins** line) before you confirm the changes and proceed with the transaction. The **fs-snapshot** plug-in displays a line in the following form for each affected file system:

```
fs-snapshot: snapshotting file_system: file_system/yum_timestamp
```

2. Verify that the system is working as expected:

   If you decide to keep the changes, you can optionally remove unwanted snapshots. To remove a Btrfs snapshot, use the command in the following form as `root`:

   ```
   btrfs subvolume delete file_system/yum_timestamp
   ```

   If you decide to revert the changes and restore a file system to a state that is saved in a snapshot, take the following steps:

   a. Determine the identifier of a particular snapshot by using the following command as `root`:

      ```
      btrfs subvolume list file_system
      ```

   b. As `root`, configure the system to mount this snapshot by default:

      ```
      btrfs subvolume set-default id file_system
      ```

   c. Restart the system. You can do so by typing the following at a shell prompt as `root`:

      ```
      reboot
      ```

For more information on logical volume management, Btrfs, and file system snapshots, see the *Fedora 17 Storage Administration Guide*[1]. For additional information about the plug-in and its configuration, refer to the **yum-fs-snapshot**(1) and **yum-fs-snapshot.conf**(5) manual pages.

Table 4.3. Supported **`fs-snapshot.conf`** directives

Section	Directive	Description
[main]	**enabled**=*value*	Allows you to enable or disable the plug-in. The *value* must be either **1** (enabled), or **0** (disabled). When installed, the plug-in is enabled by default.
	exclude=*list*	Allows you to exclude certain file systems. The value must be a space-separated *list* of mount points you do *not* want to snapshot (for example, **/srv /mnt/backup**). This option is not included in the configuration file by default.
[lvm]	**enabled**=*value*	Allows you to enable or disable the use of the plug-in on LVM volumes. The *value* must be either **1** (enabled), or **0** (disabled). This option is disabled by default.
	lvcreate_size_args=*value*	Allows you to specify the size of a logical volume snapshot. The *value* must be the **-**

[1] https://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Storage_Administration_Guide/

Section	Directive	Description
		l or **-L** command line option for the **lvcreate** utility followed by a valid argument (for example, **-l 80%ORIGIN**).

presto (*yum-presto*)

The **presto** plug-in adds support to Yum for downloading *delta RPM* packages, during updates, from repositories which have **presto** metadata enabled. Delta RPMs contain only the differences between the version of the package installed on the client requesting the RPM package and the updated version in the repository.

Downloading a delta RPM is much quicker than downloading the entire updated package, and can speed up updates considerably. Once the delta RPMs are downloaded, they must be rebuilt to apply the difference to the currently-installed package and thus create the full, updated package. This process takes CPU time on the installing machine. Using delta RPMs is therefore a tradeoff between time-to-download, which depends on the network connection, and time-to-rebuild, which is CPU-bound. Using the **presto** plug-in is recommended for fast machines and systems with slower network connections, while slower machines on very fast connections *may* benefit more from downloading normal RPM packages, that is, by disabling **presto**.

refresh-packagekit (*PackageKit-yum-plugin*)

The **refresh-packagekit** plug-in updates metadata for **PackageKit** whenever **yum** is run. The **refresh-packagekit** plug-in is installed by default.

rhnplugin (*yum-rhn-plugin*)

The **rhnplugin** provides support for connecting to `RHN Classic`. This allows systems registered with `RHN Classic` to update and install packages from this system.

Refer to the **rhnplugin**(8) manual page for more information about the plug-in.

security (*yum-plugin-security*)

Discovering information about and applying security updates easily and often is important to all system administrators. For this reason Yum provides the **security** plug-in, which extends **yum** with a set of highly-useful security-related commands, subcommands and options.

You can check for security-related updates as follows:

```
~]# yum check-update --security
Loaded plugins: langpacks, presto, refresh-packagekit, security
Limiting package lists to security relevant ones
updates-testing/updateinfo                                | 329 kB     00:00
9 package(s) needed for security, out of 270 available

ConsoleKit.x86_64                   0.4.5-1.fc15                 updates
ConsoleKit-libs.x86_64              0.4.5-1.fc15                 updates
ConsoleKit-x11.x86_64               0.4.5-1.fc15                 updates
NetworkManager.x86_64               1:0.8.999-2.git20110509.fc15  updates
NetworkManager-glib.x86_64          1:0.8.999-2.git20110509.fc15  updates
[output truncated]
```

You can then use either **yum update --security** or **yum update-minimal --security** to update those packages which are affected by security advisories. Both of these commands update all packages on the system for which a security advisory has been issued. **yum update-minimal --security** updates them to the latest packages which were released as part of a security advisory, while **yum update --security** will update all packages affected by a security advisory *to the latest version of that package available*.

In other words, if:

- the *kernel-2.6.38.4-20* package is installed on your system;
- the *kernel-2.6.38.6-22* package was released as a security update;
- then *kernel-2.6.38.6-26* was released as a bug fix update,

...then **yum update-minimal --security** will update you to *kernel-2.6.38.6-22*, and **yum update --security** will update you to *kernel-2.6.38.6-26*. Conservative system administrators may want to use **update-minimal** to reduce the risk incurred by updating packages as much as possible.

Refer to the **yum-security**(8) manual page for usage details and further explanation of the enhancements the **security** plug-in adds to **yum**.

4.5. Additional Resources

http://yum.baseurl.org/wiki/Guides

The **Yum Guides** section of the Yum wiki contains more documentation.

PackageKit

Fedora provides **PackageKit** for viewing, managing, updating, installing and uninstalling packages compatible with your system. **PackageKit** consists of several graphical interfaces that can be opened from the GNOME panel menu, or from the Notification Area when **PackageKit** alerts you that updates are available. For more information on **PackageKit's** architecture and available front ends, refer to *Section 5.3, "PackageKit Architecture"*.

5.1. Updating Packages with Software Update

You can open **Software Updates** by clicking **Applications** → **System Tools** → **Software Update** from the **Activities** menu, or running the **`gpk-update-viewer`** command at the shell prompt. In the **Software Updates** window, all available updates are listed along with the names of the packages being updated (minus the **`.rpm`** suffix, but including the CPU architecture), a short summary of the package, and, usually, short descriptions of the changes the update provides. Any updates you do not wish to install can be de-selected here by unchecking the checkbox corresponding to the update.

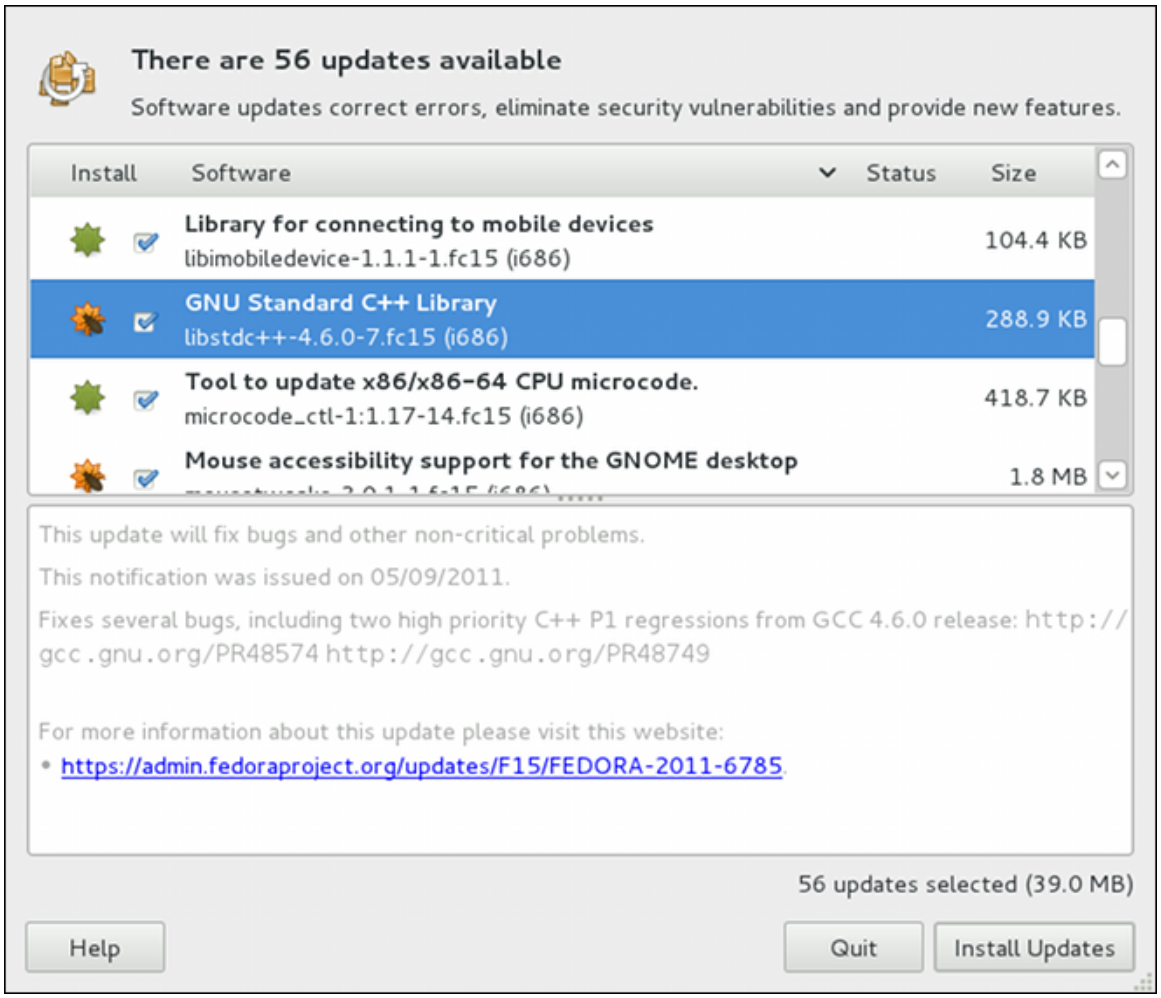


Figure 5.1. Installing updates with Software Update

The updates presented in the **Software Updates** window only represent the currently-installed packages on your system for which updates are available; dependencies of those packages, whether they are existing packages on your system or new ones, are not shown until you click **Install Updates**.

PackageKit utilizes the fine-grained user authentication capabilities provided by the **PolicyKit** toolkit whenever you request it to make changes to the system. Whenever you instruct **PackageKit** to update, install or remove packages, you will be prompted to enter the superuser password before changes are made to the system.

If you instruct **PackageKit** to update the **`kernel`** package, then it will prompt you after installation, asking you whether you want to reboot the system and thereby boot into the newly-installed kernel.

5.1.1. Setting the Update-Checking Interval

Selecting **Applications** **Other** **Software Updates** from the **Activities** menu opens the **Software Update Preferences** window. The **Update Settings** tab allows you to define the interval at which **PackageKit** checks for package updates, as well as whether or not to automatically install all updates or only security updates. Leaving the **Check for updates when using mobile broadband** box unchecked is handy for avoiding extraneous bandwidth usage when using a wireless connection on which you are charged for the amount of data you download.

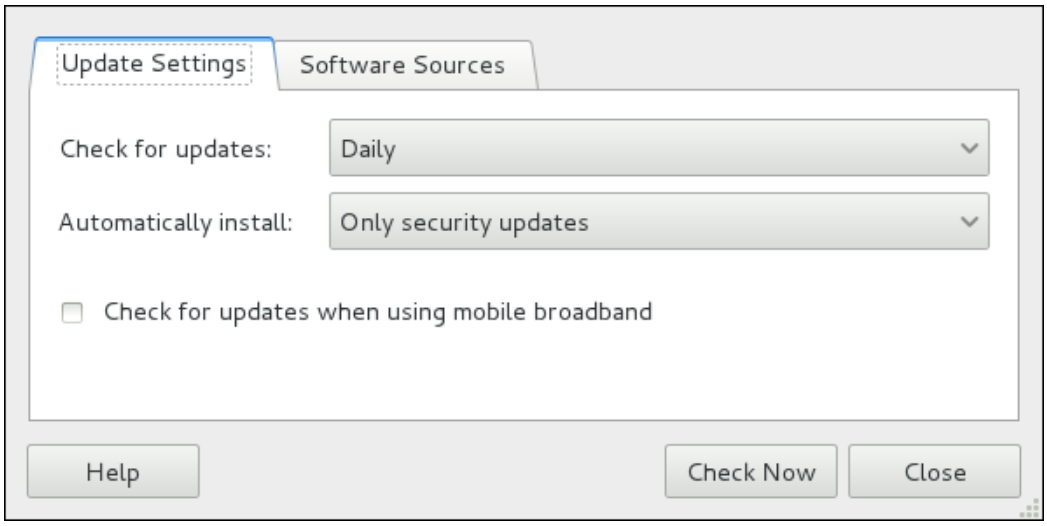


Figure 5.2. Setting PackageKit's update-checking interval

5.1.2. Setting the Software Sources

To select which package repositories to use to install software updates, select **Applications** **Other** **Software Updates** from the **Activities** menu, and click the **Software Sources** tab of the **Software Update Preferences** window.

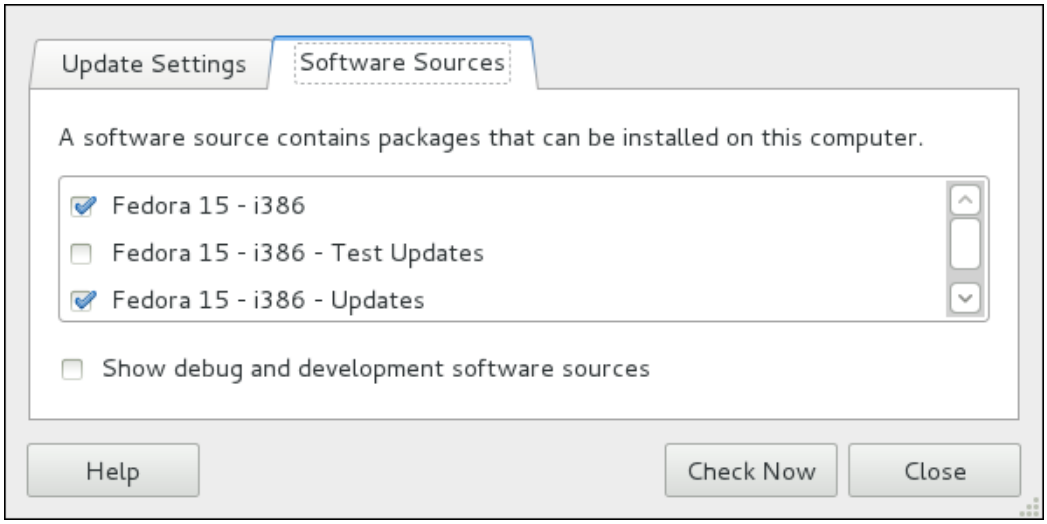


Figure 5.3. Setting PackageKit's software sources

PackageKit refers to **Yum** repositories as software sources. It obtains all packages from enabled software sources.The **Software Sources** tab shows the repository name, as written on the **name=*My Repository Name*** field of all [*repository*] sections in the **/etc/yum.conf** configuration file, and in all ***repository*.repo** files in the **/etc/yum.repos.d/** directory.

Entries which are checked in the **Enabled** column indicate that the corresponding repository will be used to locate packages to satisfy all update and installation requests (including dependency resolution). The **Enabled** column corresponds to the **enabled=<*1 or 0*>** field in [*repository*] sections. Checking an unchecked box enables the Yum repository, and unchecking it disables it. Performing either function causes **PolicyKit** to prompt for superuser authentication to enable or disable the repository. **PackageKit** actually inserts the **enabled=<*1 or 0*>** line into the correct [*repository*] section if it does not exist, or changes the value if it does. This means that enabling or disabling a repository through the **Software Sources** window causes that change to persist after closing the window or rebooting the system. The ability to quickly enable and disable repositories based on our needs is a highly-convenient feature of **PackageKit**.

Note that it is not possible to add or remove **Yum** repositories through **PackageKit**.

Showing source RPM, test, and debuginfo repositories

Checking the box at the bottom of the **Software Sources** tab causes **PackageKit** to display source RPM, testing and debuginfo repositories as well. This box is unchecked by default.

5.2. Using Add/Remove Software

PackageKit's **Software Update** GUI window is a separate application from its **Add/Remove Software** application, although the two have intuitively similar interfaces. To find and install a new package, select **Applications**□□□ **System Tools**□□□ **Add/Remove Software** from the **Activities** menu, or run the **gpk-application** command at the shell prompt.

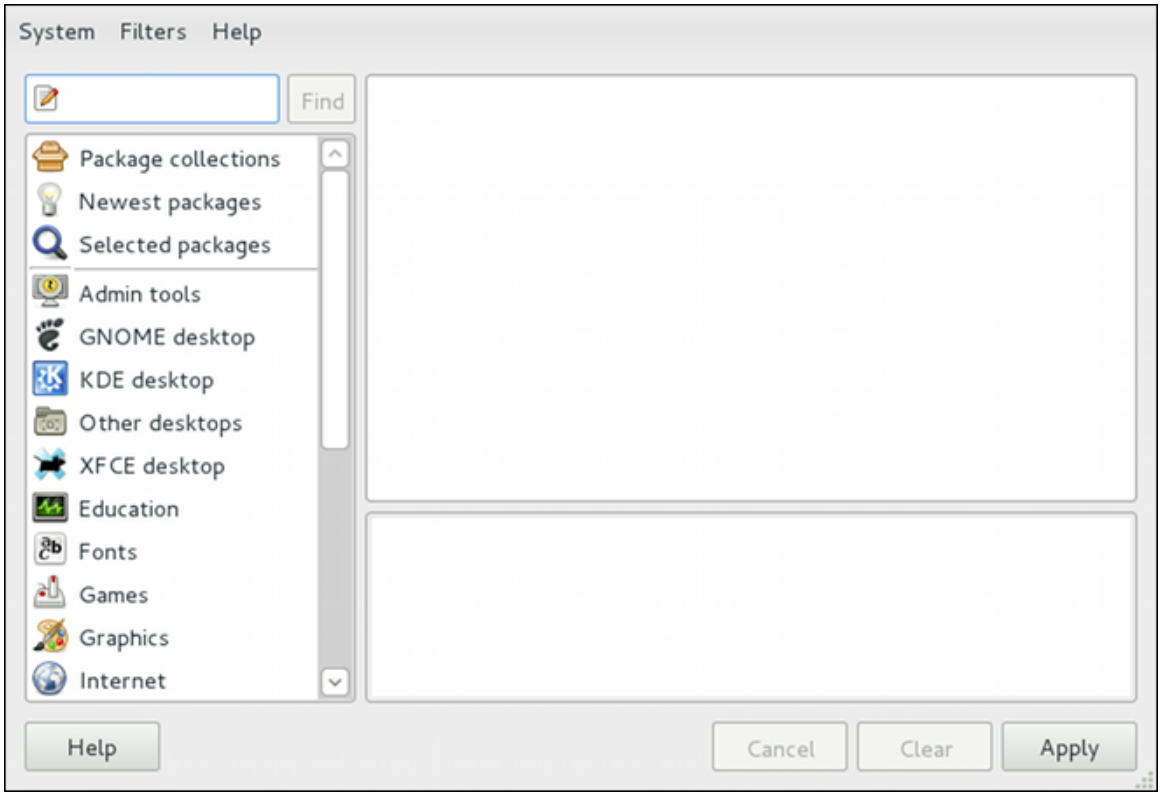


Figure 5.4. PackageKit's Add/Remove Software window

5.2.1. Refreshing Software Sources (Yum Repositories)

To enable or disable a **Yum** repository, open a dialog box by sclicking **System□□□ Software Sources**, and select the **Software Sources** tab. Refer to *Section 5.1.2, "Setting the Software Sources"* for more information on available configuration options.

After enabling and/or disabling the correct **Yum** repositories, make sure that you have the latest list of available packages. Click on **System□□□ Refresh Package Lists** and **PackageKit** will obtain the latest lists of packages from all enabled software sources, that is, **Yum** repositories.

5.2.2. Finding Packages with Filters

You can view the list of all *configured* and unfiltered (see below) **Yum** repositories by opening **Add/ Remove Software** and clicking **System□□□ Software Sources**. Once the software sources have been updated, it is often beneficial to apply some filters so that **PackageKit** retrieves the results of our **Find** queries faster. This is especially helpful when performing many package searches. Four of the filters in the **Filters** drop-down menu are used to split results by matching or not matching a single criterion. By default when **PackageKit** starts, these filters are all unapplied (**No Filter**), but once you do filter by one of them, that filter remains set until you either change it or close **PackageKit**.

Because you are usually searching for available packages that are *not* installed on the system, click **Filters□□□ Installed** and select the **Only Available** radio button.

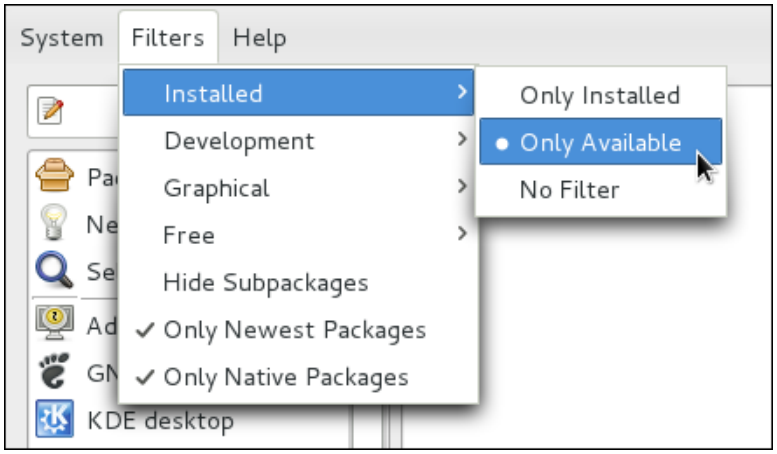


Figure 5.5. Filtering out already-installed packages

Also, unless we require development files such as C header files, we can filter for **Only End User Files** and, in doing so, filter out all of the ***package_name*-devel** packages we are not interested in.

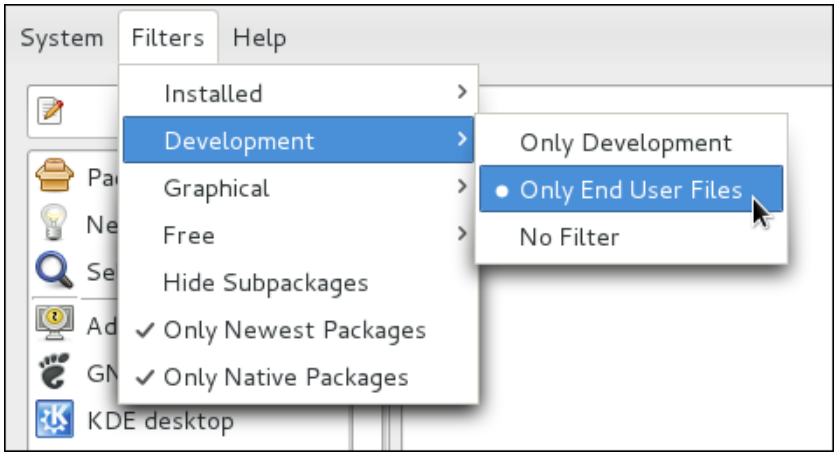


Figure 5.6. Filtering out development packages from the list of Find results

The two remaining filters with submenus are:

Graphical

Narrows the search to either applications which provide a GUI interface (**Only Graphical**) or those that do not. This filter is useful when browsing for GUI applications that perform a specific function.

Free

Search for packages which are considered to be free software Refer to the *Fedora Licensing List*[1] for details on approved licenses.

The remaining checkbox filters are always either checked or unchecked. They are:

Hide Subpackages

Checking the **Hide Subpackages** checkbox filters out generally-uninteresting packages that are typically only dependencies of other packages that we want. For example, checking **Hide Subpackages** and searching for ***package*** would cause the following related packages to be filtered out of the **Find** results (if it exists):

[1] https://fedoraproject.org/wiki/Licensing#SoftwareLicenses

- ***package*-devel**
- ***package*-libs**
- ***package*-libs-devel**
- ***package*-debuginfo**

Only Newest Packages

Checking **Only Newest Packages** filters out all older versions of the same package from the list of results, which is generally what we want.



Using the Only Newest Packages filter

Checking **Only Newest Packages** filters out all but the most recent version of any package from the results list. This filter is often combined with the **Only Available** filter to search for the latest available versions of new (not installed) packages.

Only native packages

Checking the **Only Native Packages** box on a multilib system causes **PackageKit** to omit listing results for packages compiled for the architecture that runs in *compatibility mode*. For example, enabling this filter on a 64-bit system with an AMD64 CPU would cause all packages built for the 32-bit x86 CPU architecture not to be shown in the list of results, even though those packages are able to run on an AMD64 machine. Packages which are architecture-agnostic (i.e. *noarch* packages such as **crontabs-1.10-32.1.el6.noarch.rpm**) are never filtered out by checking **Only Native Packages**. This filter has no affect on non-multilib systems, such as x86 machines.

5.2.3. Installing and Removing Packages (and Dependencies)

With the two filters selected, **Only Available** and **Only End User Files**, search for the **htop** interactive process viewer and highlight the package. You now have access to some very useful information about it, including: a clickable link to the project homepage; the **Yum** package group it is found in, if any; the license of the package; a pointer to the GNOME menu location from where the application can be opened, if applicable; and the size of the package, which is relevant when we download and install it.

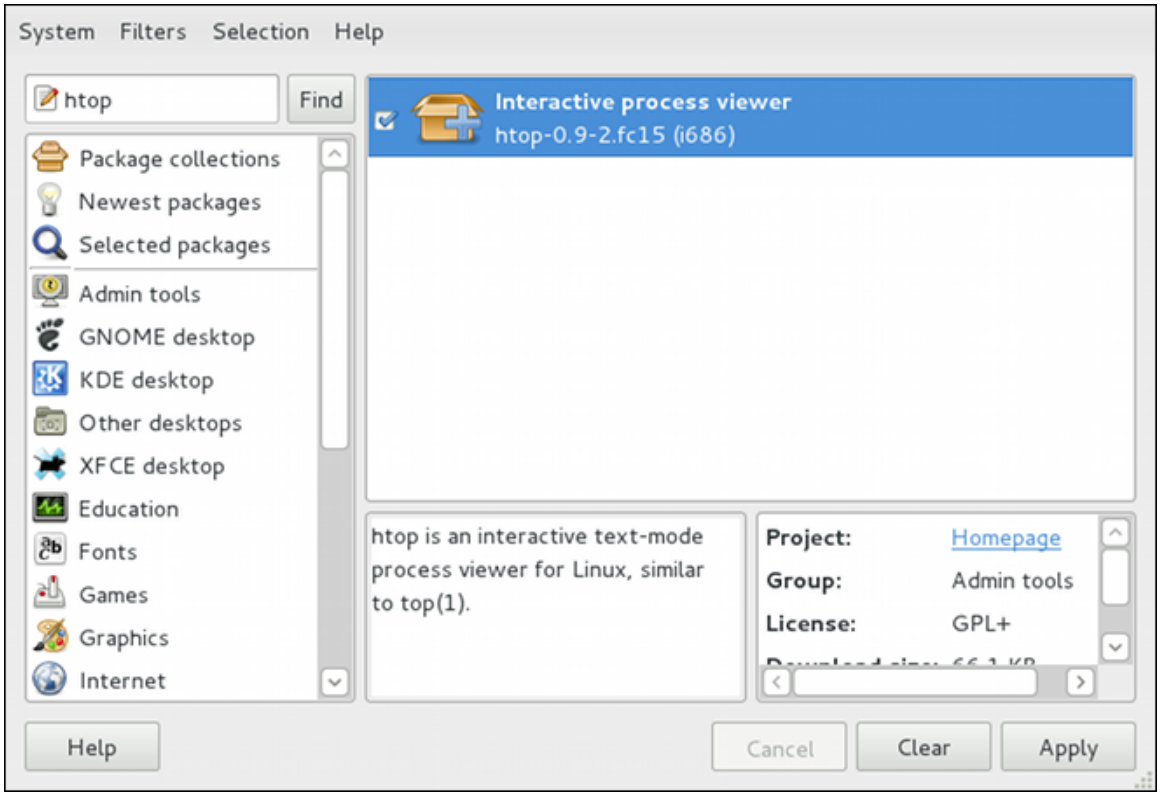


Figure 5.7. Viewing and installing a package with PackageKit's Add/Remove Software window

When the checkbox next to a package or group is checked, then that item is already installed on the system. Checking an unchecked box causes it to be *marked* for installation, which only occurs when the **Apply** button is clicked. In this way, you can search for and select multiple packages or package groups before performing the actual installation transactions. Additionally, you can remove installed packages by unchecking the checked box, and the removal will occur along with any pending installations when **Apply** is pressed. Dependency resolution , which may add additional packages to be installed or removed, is performed after pressing **Apply**. **PackageKit** will then display a window listing those additional packages to install or remove, and ask for confirmation to proceed.

Check **htop** and click the **Apply** button. You will then be prompted for the superuser password; enter it, and **PackageKit** will install **htop**. One nice feature of **PackageKit** is that, following installation, it sometimes presents you with a list of your newly-installed applications and offer you the choice of running them immediately. Alternatively, you will remember that finding a package and selecting it in the **Add/Remove Software** window shows you the **Location** of where in the GNOME menus its application shortcut is located, which is helpful when you want to run it.

Once it is installed, you can run **`htop`**, a colorful and enhanced version of the **`top`** process viewer, by opening a shell prompt and entering:

```
htop
```

htop is nifty, but we decide that **`top`** is good enough for us and we want to uninstall it. Remembering that we need to change the **Only Available** filter we recently used to install it to **Only Installed** in **Filters□□□ Installed**, we search for **htop** again and uncheck it. The program did not install any dependencies of its own; if it had, those would be automatically removed as well, as long as they were not also dependencies of any other packages still installed on our system.

Removing a package when other packages depend on it

Although **PackageKit** automatically resolves dependencies during package installation and removal, it is unable to remove a package without also removing packages which depend on it. This type of operation can only be performed by **RPM**, is not advised, and can potentially leave your system in a non-functioning state or cause applications to misbehave and/or crash.

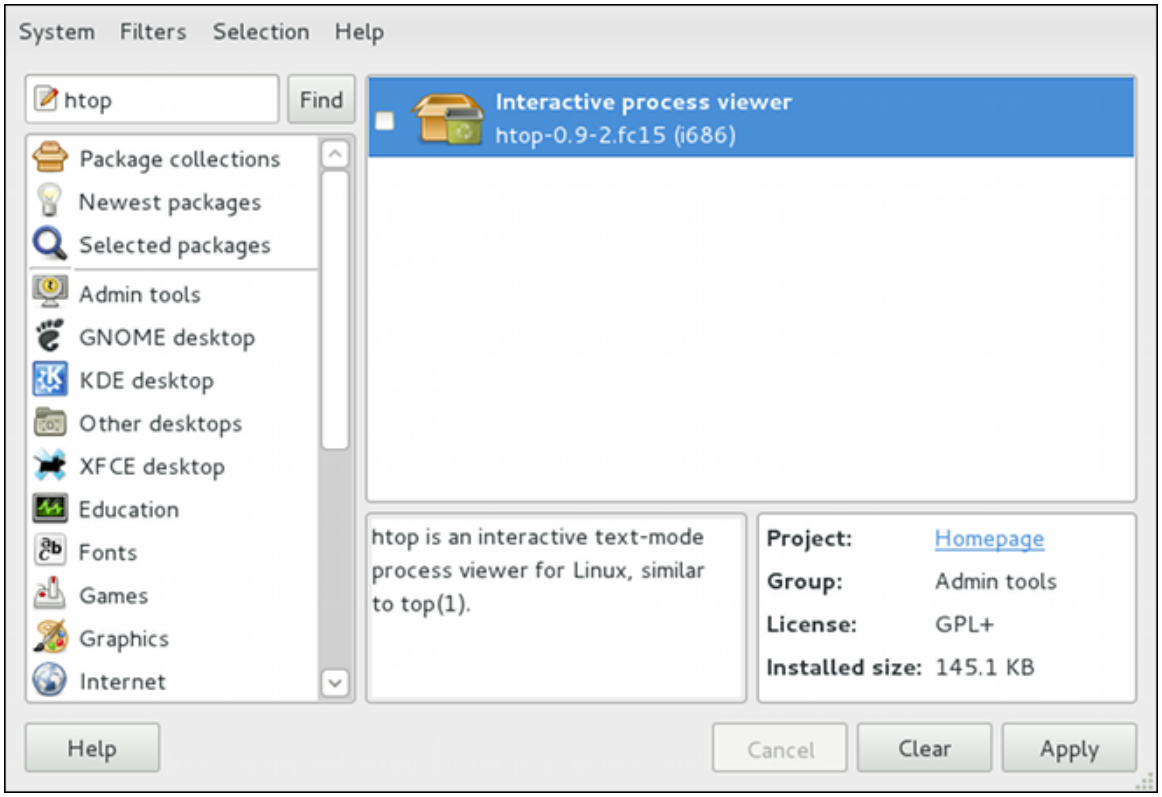


Figure 5.8. Removing a package with PackageKit's Add/Remove Software window

5.2.4. Installing and Removing Package Groups

PackageKit also has the ability to install **Yum** package groups, which it calls **Package collections**. Clicking on **Package collections** in the top-left list of categories in the **Software Updates** window allows us to scroll through and find the package group we want to install. In this case, we want to install Czech language support (the **Czech Support** group). Checking the box and clicking **Apply** informs us how many *additional* packages must be installed in order to fulfill the dependencies of the package group.

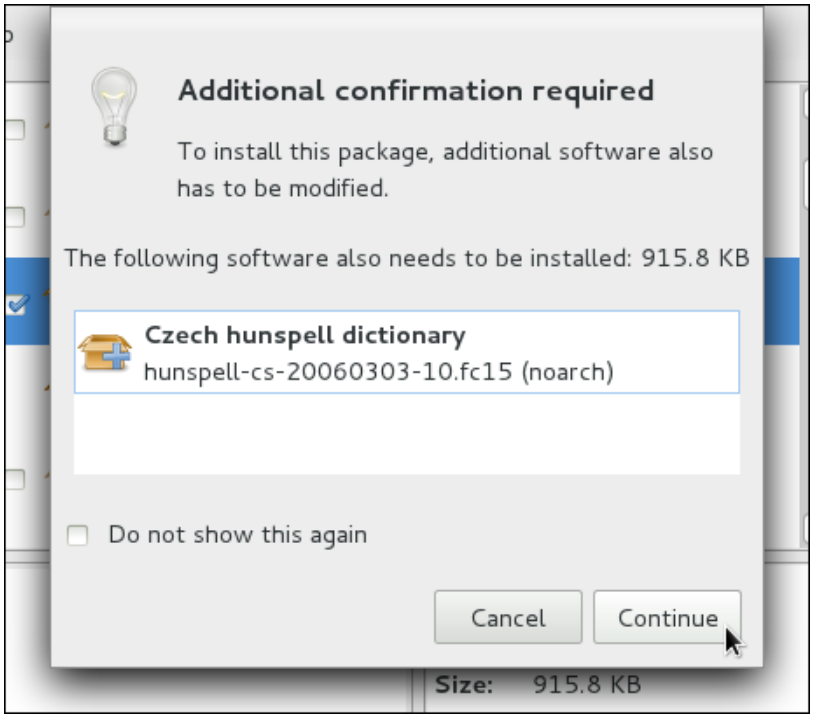


Figure 5.9. Installing the Czech Support package group

Similarly, installed package groups can be uninstalled by selecting **Package collections**, unchecking the appropriate checkbox, and applying.

5.2.5. Viewing the Transaction Log

PackageKit maintains a log of the transactions that it performs. To view the log, from the **Add/Remove Software** window, click **System** **Software Log**, or run the **gpk-log** command at the shell prompt.

The **Software Log Viewer** shows the **Action**, such as **Updated Packages** or **Installed Packages**, the **Date** on which that action was performed, the **Username** of the user who performed the action, and the front end **Application** the user used (such as **Add/Remove Software**, or **Update System**). The **Details** column provides the types of the transactions, such as **Updated**, **Installed**, or **Removed**, as well as the list of packages the transactions were performed on.

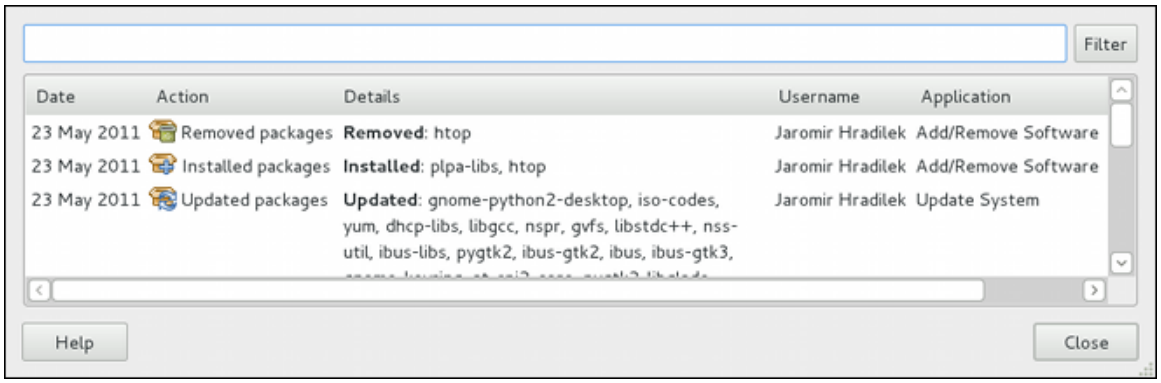


Figure 5.10. Viewing the log of package management transactions with the Software Log Viewer

Typing the name of a package in the top text entry field filters the list of transactions to those which affected that package.

5.3. PackageKit Architecture

Fedora provides the **PackageKit** suite of applications for viewing, updating, installing and uninstalling packages and package groups compatible with your system. Architecturally, **PackageKit** consists of several graphical front ends that communicate with the **packagekitd** daemon back end, which communicates with a package manager-specific back end that utilizes **Yum** to perform the actual transactions, such as installing and removing packages, etc.

Table 5.1, "PackageKit GUI windows, menu locations, and shell prompt commands" shows the name of the GUI window, how to start the window from the GNOME desktop or from the **Add/Remove Software** window, and the name of the command line application that opens that window.

Table 5.1. PackageKit GUI windows, menu locations, and shell prompt commands

Window Title	Function	How to Open	Shell Command
Add/Remove Software	Install, remove or view package info	From the GNOME panel: **System** □□ **Administration** □□ **Add/Remove Software**	gpk-application
Software Update	Perform package updates	From the GNOME panel: **System** □□ **Administration** □□ **Software Update**	gpk-update-viewer
Software Sources	Enable and disable **Yum** repositories	From **Add/Remove Software**: **System** □□ **Software Sources**	gpk-repo
Software Log Viewer	View the transaction log	From **Add/Remove Software**: **System** □□ **Software Log**	gpk-log
Software Update Preferences	Set **PackageKit** preferences		gpk-prefs
(Notification Area Alert)	Alerts you when updates are available	From the GNOME panel: **System** □□ **Preferences** □□ **Startup Applications**, **Startup Programs** tab	gpk-update-icon

The **packagekitd** daemon runs outside the user session and communicates with the various graphical front ends. The **packagekitd** daemon[2] communicates via the **DBus** system message bus with another back end, which utilizes **Yum**'s Python API to perform queries and make changes to the system. On Linux systems other than Red Hat Enterprise Linux and Fedora, **packagekitd** can communicate with other back ends that are able to utilize the native package manager for that system. This modular architecture provides the abstraction necessary for the graphical interfaces to work with many different package managers to perform essentially the same types of package management tasks. Learning how to use the **PackageKit** front ends means that you can use the same familiar

[2] System daemons are typically long-running processes that provide services to the user or to other programs, and which are started, often at boot time. Daemons respond to the **systemctl** command and can be turned on or off permanently by using the **systemctl enable** or **systemctl disable**commands. They can typically be recognized by a "*d*" appended to their name, such as the **packagekitd** daemon. Refer to *Chapter 8, Services and Daemons* for information about system services.

graphical interface across many different Linux distributions, even when they utilize a native package manager other than **Yum**.

In addition, **PackageKit**'s separation of concerns provides reliability in that a crash of one of the GUI windows—or even the user's X Window session—will not affect any package management tasks being supervised by the **packagekitd** daemon, which runs outside of the user session.

All of the front end graphical applications discussed in this chapter are provided by the **gnome-packagekit** package instead of by **PackageKit** and its dependencies. Users working in a KDE environment may prefer to install the **kpackagekit** package, which provides a KDE interface for **PackageKit**.

Finally, **PackageKit** also comes with a console-based front end called **pkcon**.

5.4. Additional Resources

PackageKit home page — *http://www.packagekit.org/index.html*
Information about and mailing lists for **PackageKit**.

PackageKit FAQ — *http://www.packagekit.org/pk-faq.html*
An informative list of Frequently Asked Questions for the **PackageKit** software suite.

PackageKit Feature Matrix — *http://www.packagekit.org/pk-matrix.html*
Cross-reference **PackageKit**-provided features with the long list of package manager back ends.

Part III. Networking

This part describes how to configure the network on Fedora.

NetworkManager

NetworkManager is a dynamic network control and configuration system that attempts to keep network devices and connections up and active when they are available. **NetworkManager** consists of a core daemon, a GNOME Notification Area applet that provides network status information, and graphical configuration tools that can create, edit and remove connections and interfaces. **NetworkManager** can be used to configure the following types of connections: Ethernet, wireless, mobile broadband (such as cellular 3G), and DSL and PPPoE (Point-to-Point over Ethernet). In addition, **NetworkManager** allows for the configuration of network aliases, static routes, DNS information and VPN connections, as well as many connection-specific parameters. Finally, **NetworkManager** provides a rich API via D-Bus which allows applications to query and control network configuration and state.

Previous versions of Fedora included the **Network Administration Tool**, which was commonly known as **`system-config-network`** after its command line invocation. In Fedora 17, **NetworkManager** replaces the former **Network Administration Tool** while providing enhanced functionality, such as user-specific and mobile broadband configuration. It is also possible to configure the network in Fedora 17 by editing interface configuration files; refer to *Chapter 7, Network Interfaces* for more information.

NetworkManager may be installed by default on Fedora. To ensure that it is, first run the following command as the root user:

```
~]# yum install NetworkManager
```

6.1. The NetworkManager Daemon

The **NetworkManager** daemon runs with root privileges and is usually configured to start up at boot time. You can determine whether the **NetworkManager** daemon is running by entering this command as root:

```
~]# service NetworkManager status
NetworkManager (pid  1527) is running...
```

The **`service`** command will report **`NetworkManager is stopped`** if the **NetworkManager** service is not running. To start it for the current session:

```
~]# service NetworkManager start
```

Run the **`chkconfig`** command to ensure that **NetworkManager** starts up every time the system boots:

```
~]# chkconfig NetworkManager on
```

For more information on starting, stopping and managing services and runlevels, refer to *Chapter 8, Services and Daemons*.

6.2. Interacting with NetworkManager

Users do not interact with the **NetworkManager** system service directly. Instead, you can perform network configuration tasks via **NetworkManager**'s Notification Area applet. The applet has multiple states that serve as visual indicators for the type of connection you are currently using.



Figure 6.1. NetworkManager applet states

If you do not see the **NetworkManager** applet in the GNOME panel, and assuming that the **NetworkManager** package is installed on your system, you can start the applet by running the following command as a normal user (not root):

```
~]$ nm-applet &
```

After running this command, the applet appears in your Notification Area.

6.2.1. Connecting to a Network

When you click on the applet icon, you are presented with:

- a list of categorized networks you are currently connected to (such as **Wired** and **Wireless**);
- a list of all **Available Networks** that **NetworkManager** has detected;
- options for connecting to any configured Virtual Private Networks (VPNs); and,
- options for connecting to hidden or new wireless networks.

If you are connected to a network, its name is presented first under its network type, such as **Wired** or **Wireless** with a bulletpoint to the left. When many networks are available, such as wireless access points, the **More** networks expandable menu entry appears.

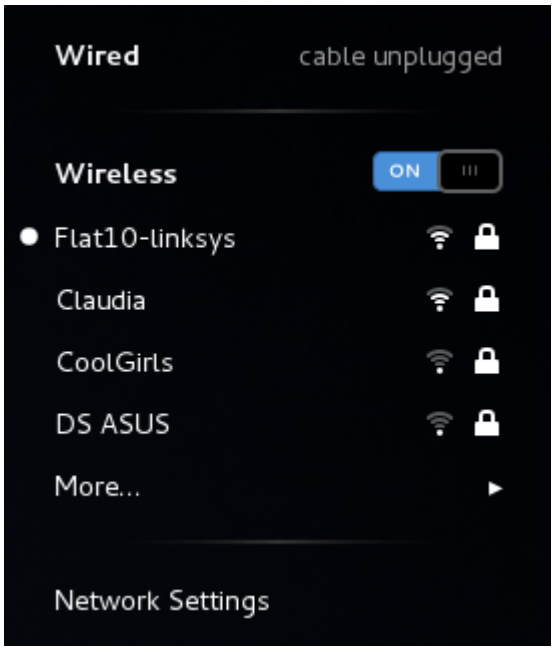


Figure 6.2. The **NetworkManager** applet's drop-down menu, showing all available and connected-to networks

6.2.2. Configuring New and Editing Existing Connections

Click on the **NetworkManager** applet to open the drop-down menu, this is the main point of entry for interacting with **NetworkManager** to configure connections.

If the system has detected a wired connection, the **Wired** menu entry will appear. If the system has detected a wireless card, then you will also see a **Wireless** menu entry. Clicking the **Wired** and **Wireless** labels or the associated ON OFF indicator to the right will toggle the status between ON and OFF.

Finally, clicking on the **Network Settings** menu entry opens the **Network** window, from where you can view some basic network configuration information and initiate configuration tasks.

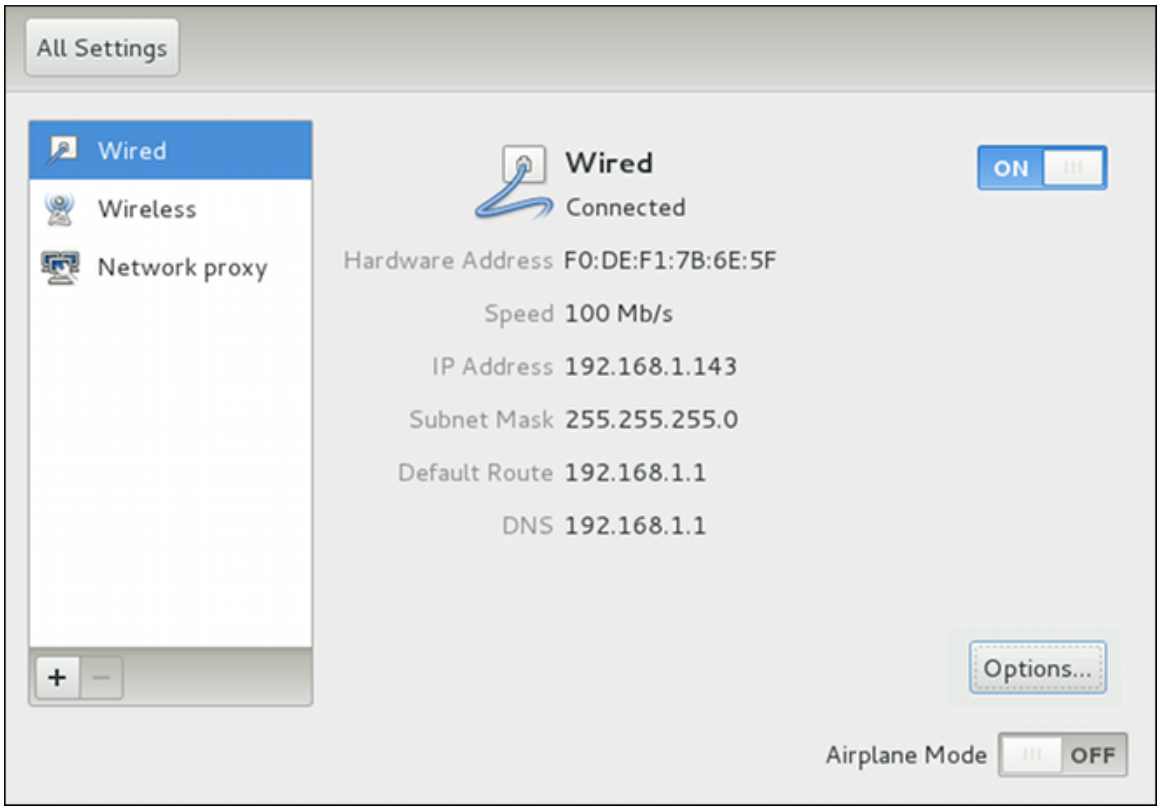


Figure 6.3. Configure networks using the Network window

Then, to configure:

- wired Ethernet connections, click on **Wired** followed by **Options** and proceed to *Section 6.3.1, "Establishing a Wired (Ethernet) Connection"*;
- wireless connections, click on **Wireless** followed by **Options** and proceed to *Section 6.3.2, "Establishing a Wireless Connection"*; or,
- mobile broadband connections, proceed to *Section 6.3.3, "Establishing a Mobile Broadband Connection"*; or,
- VPN connections, click on the **VPN** menu entry followed by **Options** and proceed to *Section 6.3.4, "Establishing a VPN Connection"*. If there is no VPN menu entry click on the plus sign at the bottom. A dialog box appears. Ensure the interface is set to VPN. Click the **Create** button to open the **Choose a VPN Connection Type** assistant. Proceed to *Step 5*

6.2.3. Connecting to a Network Automatically

For any connection type you add or configure, you can choose whether you want **NetworkManager** to try to connect to that network automatically when it is available.

Procedure 6.1. Configuring NetworkManager to Connect to a Network Automatically When Detected

1. Click on the **NetworkManager** applet icon in the Notification Area.

2. Click **Network Settings**.

   The **Network** window appears.

3. Select the type of connection from the left-hand-side menu.

4. Click on **Configure**

5. Select **Connect automatically** to cause **NetworkManager** to auto-connect to the connection whenever **NetworkManager** detects that it is available. Unselect the checkbox if you do not want **NetworkManager** to connect automatically. If the box is unchecked, you will have to select that connection manually in the **NetworkManager** applet's initial menu to cause it to connect.

6.2.4. User and System Connections

NetworkManager connections are always either *user connections* or *system connections*. Depending on the system-specific policy that the administrator has configured, users may need root privileges to create and modify system connections. **NetworkManager**'s default policy enables users to create and modify user connections, but requires them to have root privileges to add, modify or delete system connections.

User connections are so-called because they are specific to the user who creates them. In contrast to system connections, whose configurations are stored under the **`/etc/sysconfig/network-scripts/`** directory (mainly in **`ifcfg-<network_type>`** interface configuration files), user connection settings are stored in the GConf configuration database and the GNOME keyring, and are only available during login sessions for the user who created them. Thus, logging out of the desktop session causes user-specific connections to become unavailable.



Increase security by making VPN connections user-specific

Because **NetworkManager** uses the GConf and GNOME keyring applications to store user connection settings, and because these settings are specific to your desktop session, it is highly recommended to configure your personal VPN connections as user connections. If you do so, other non-root users on the system cannot view or access these connections in any way.

System connections, on the other hand, become available at boot time and can be used by other users on the system without first logging in to a desktop session.

NetworkManager can quickly and conveniently convert user to system connections and vice versa. Converting a user connection to a system connection causes **NetworkManager** to create the relevant interface configuration files under the **`/etc/sysconfig/network-scripts/`** directory, and to delete the GConf settings from the user's session. Conversely, converting a system to a user-specific connection causes **NetworkManager** to remove the system-wide configuration files and create the corresponding GConf/GNOME keyring settings.



Figure 6.4. The **Available to all users** checkbox controls whether connections are user-specific or system-wide

Procedure 6.2. Changing a Connection to be User-Specific instead of System-Wide, or Vice-Versa



Root privileges may be required

Depending on the system's policy, you may need root privileges on the system in order to change whether a connection is user-specific or system-wide.

1. Click on the **NetworkManager** applet icon in the Notification Area and click **Network Settings**. The **Network** window appears.
2. Select the menu entry for the type of network connection you want to configure.
3. Select the **Configure** button.
4. Check the **Available to all users** checkbox to ask **NetworkManager** to make the connection a system-wide connection. Depending on system policy, you may then be prompted for the root password by the **PolicyKit** application. If so, enter the root password to finalize the change.

   Conversely, uncheck the **Available to all users** checkbox to make the connection user-specific.

6.3. Establishing Connections

6.3.1. Establishing a Wired (Ethernet) Connection

To establish a wired network connection, click on the **NetworkManager** applet to open its menu, then click on **Network Settings**. This opens the **Network** window.

Select the **Wired** menu entry and then click **Configure**.

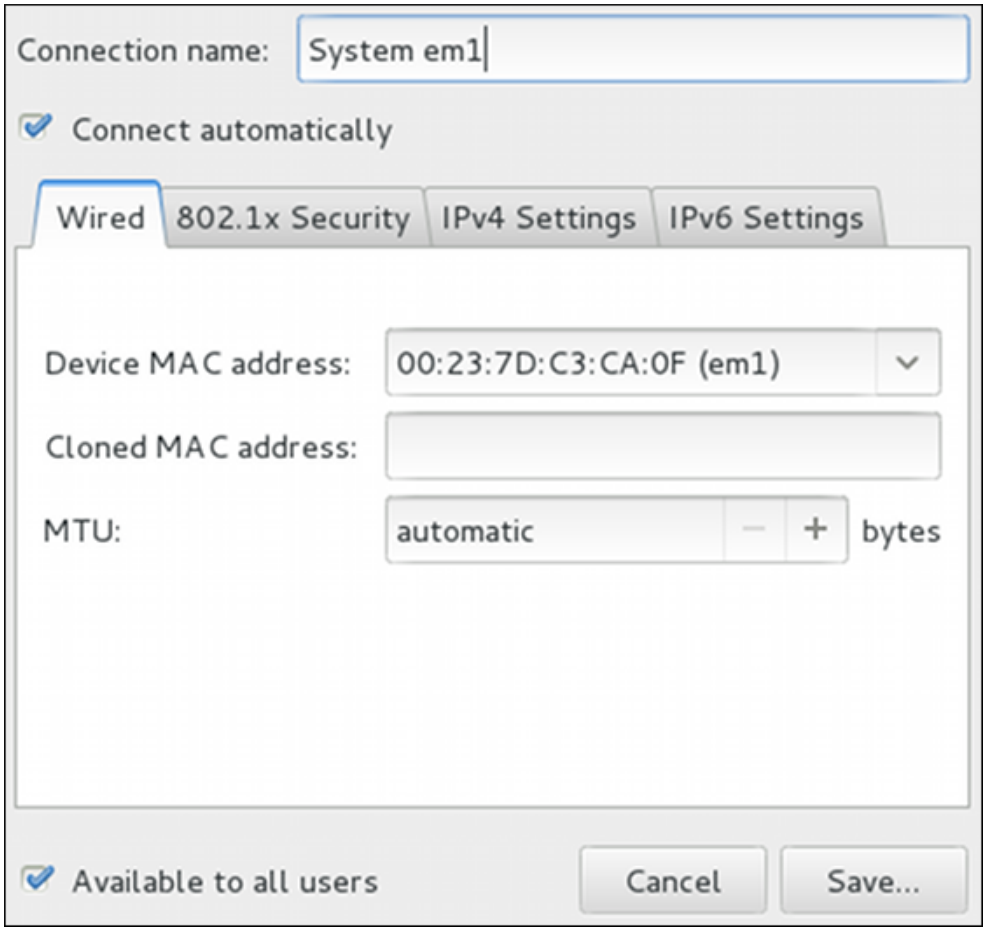


Figure 6.5. Editing the newly-created Wired connection 1

The system startup scripts create and configure a single wired connection called **System eth0** by default on all systems. Although you can edit **System eth0**, creating a new wired connection for your custom settings is recommended. You can create a new wired connection by selecting the **Wired** tab and clicking the **Add** button.

The dialog for adding and editing connections is the same

When you add a new connection by clicking the **Add** button, **NetworkManager** creates a new configuration file for that connection and then opens the same dialog that is used for editing an existing connection. There is no difference between these dialogs. In effect, you are always editing a connection; the difference only lies in whether that connection previously existed or was just created by **NetworkManager** when you clicked **Add**.

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the **Editing** dialog are common to all connection types:

- **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the **Wired** tab of the **Network Connections** window.

- **Connect automatically** — Check this box if you want **NetworkManager** to auto-connect to this connection when it is available. Refer to *Section 6.2.3, "Connecting to a Network Automatically"* for more information.
- **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to *Section 6.2.4, "User and System Connections"* for details.

Configuring the Wired Tab

The final two configurable settings are located within the **Wired** tab itself: the first is a text-entry field where you can specify a MAC (Media Access Control) address, and the second allows you to specify the MTU (Maximum Transmission Unit) value. Normally, you can leave the **MAC address** field blank and the **MTU** set to **`automatic`**. These defaults will suffice unless you are associating a wired connection with a second or specific NIC, or performing advanced networking. In such cases, refer to the following descriptions:

MAC Address

Network hardware such as a Network Interface Card (NIC) has a unique MAC address (Media Access Control; also known as a *hardware address*) that identifies it to the system. Running the **`ip addr`** command will show the MAC address associated with each interface. For example, in the following **`ip addr`** output, the MAC address for the **eth0** interface (which is **`52:54:00:26:9e:f1`**) immediately follows the **`link/ether`** keyword:

```
~]# ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 16436 qdisc noqueue state UNKNOWN
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UNKNOWN qlen
 1000
    link/ether 52:54:00:26:9e:f1 brd ff:ff:ff:ff:ff:ff
    inet 192.168.122.251/24 brd 192.168.122.255 scope global eth0
    inet6 fe80::5054:ff:fe26:9ef1/64 scope link
       valid_lft forever preferred_lft forever
```

A single system can have one or more NICs installed on it. The **MAC address** field therefore allows you to associate a specific NIC with a specific connection (or connections). As mentioned, you can determine the MAC address using the **`ip addr`** command, and then copy and paste that value into the **MAC address** text-entry field.

MTU

The MTU (Maximum Transmission Unit) value represents the size in bytes of the largest packet that the connection will use to transmit. This value defaults to `1500` when using IPv4, or a variable number `1280` or higher for IPv6, and does not generally need to be specified or changed.

Saving Your New (or Modified) Connection and Making Further Configurations

Once you have finished editing your wired connection, click the **Apply** button and **NetworkManager** will immediately save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the **NetworkManager** Notification Area applet. See *Section 6.2.1, "Connecting to a Network"* for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the **Network Connections** window and clicking **Edit** to return to the **Editing** dialog.

Then, to configure:

- port-based Network Access Control (PNAC), click the **802.1x Security** tab and proceed to *Section 6.4.1, "Configuring 802.1x Security"*;
- IPv4 settings for the connection, click the **IPv4 Settings** tab and proceed to *Section 6.4.4, "Configuring IPv4 Settings"*; or,
- IPv6 settings for the connection, click the **IPv6 Settings** tab and proceed to *Section 6.4.5, "Configuring IPv6 Settings"*.

6.3.2. Establishing a Wireless Connection

This section explains how to use **NetworkManager** to configure a wireless (also known as Wi-Fi or 802.1*a*/*b*/*g*/*n*) connection to an Access Point.

To configure a mobile broadband (such as 3G) connection, refer to *Section 6.3.3, "Establishing a Mobile Broadband Connection"*.

Quickly Connecting to an Available Access Point

The easiest way to connect to an available access point is to click on the **NetworkManager** applet, locate the *Service Set Identifier* (SSID) of the access point in the list of available networks, and click on it. If the access point is secured, a dialog prompts you for authentication.

NetworkManager tries to auto-detect the type of security used by the access point. If there are multiple possibilities, **NetworkManager** guesses the security type and presents it in the **Wireless security** dropdown menu. To see if there are multiple choices, click the **Wireless security** dropdown menu and select the type of security the access point is using. If you are unsure, try connecting to each type in turn. Finally, enter the key or passphrase in the **Password** field. Certain password types, such as a 40-bit WEP or 128-bit WPA key, are invalid unless they are of a requisite length. The **Connect** button will remain inactive until you enter a key of the length required for the selected security type. To learn more about wireless security, refer to *Section 6.4.2, "Configuring Wireless Security"*.

If **NetworkManager** connects to the access point successfully, its applet icon will change into a graphical indicator of the wireless connection's signal strength.



Figure 6.6. Applet icon indicating wireless connection signal strength

Connecting to a Hidden Wireless Network

All access points have a *Service Set Identifier* (SSID) to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is *hidden*, and will not show up in **NetworkManager**'s list of **Available** networks. You can still connect to a wireless access point that is hiding its SSID as long as you know its SSID, authentication method, and secrets.

To connect to a hidden wireless network, click **NetworkManager**'s applet icon and then click **Network Settings**. The **Network** window appears. Select the **Wireless** menu entry and then click to the right of the **Network Name** to activate the drop-down list. Select **Other**. The **Hidden wireless network** dialog window appears.

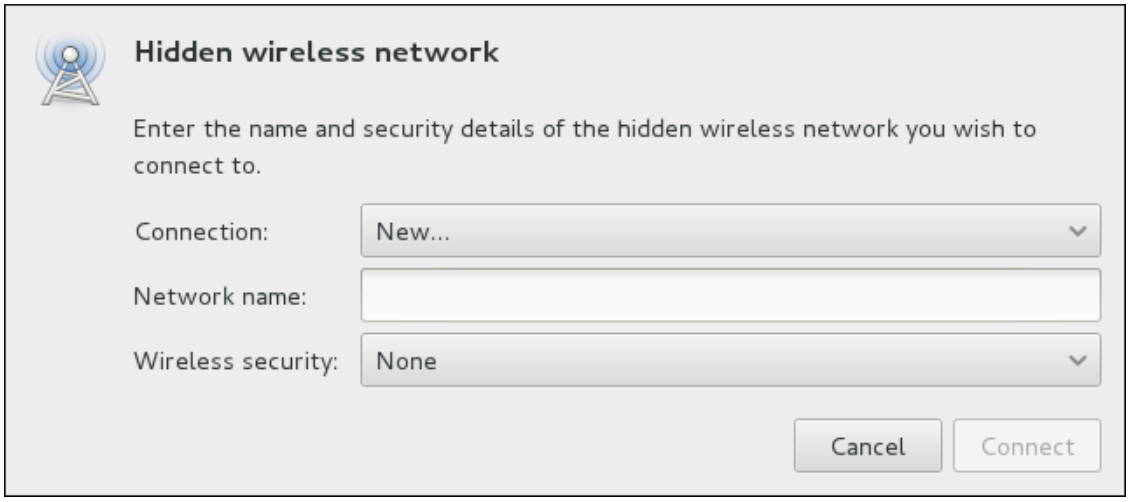


Figure 6.7. Hidden wireless network dialog window

If you have connected to the hidden network before, use the **Connection** drop-down list to select it, and click **Connect**. If you have not, leave the **Connection** dropdown as **New...**, enter the SSID of the hidden network, select its **Wireless security** method, enter the correct authentication secrets, and click **Connect**.

For more information on wireless security settings, refer to *Section 6.4.2, "Configuring Wireless Security"*.

Editing a Connection, or Creating a Completely New One

You can create a new connection by clicking on the **NetworkManager** applet to open its menu.

1. Click on the **NetworkManager** applet icon in the Notification Area and click **Network Settings**. The **Network** window appears.
2. Select the **Wireless** menu entry.
3. Click to the right of the **Network Name** to activate the drop-down list.
4. Select the SSID you want to connect to.
5. Click the **Configure** button. The editing a wireless connection window appears.

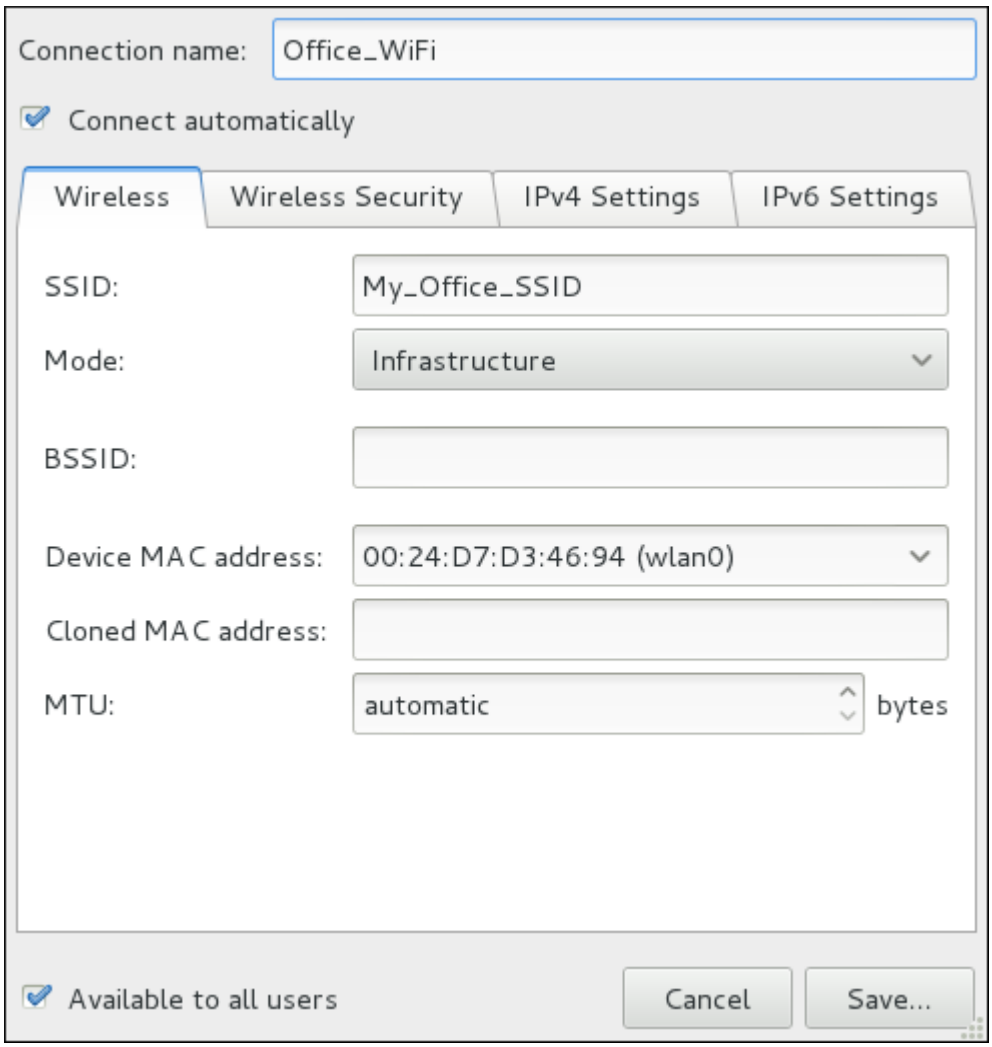


Figure 6.8. Editing the newly-created Wireless connection

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the **Editing** dialog are common to all connection types:

- **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the **Wireless** tab of the **Network Connections** window. By default, wireless connections are named the same as the *SSID* of the wireless access point. You can rename the wireless connection without affecting its ability to connect, as in the example above, but it is recommended to retain the SSID name.

- **Connect automatically** — Check this box if you want **NetworkManager** to auto-connect to this connection when it is available. Refer to *Section 6.2.3, "Connecting to a Network Automatically"* for more information.

- **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to *Section 6.2.4, "User and System Connections"* for details.

Configuring the Wireless Tab

SSID

All access points have a *Service Set identifier* to identify them. However, an access point may be configured not to broadcast its SSID, in which case it is *hidden*, and will not show up in **NetworkManager**'s list of **Available** networks. You can still connect to a wireless access point that is hiding its SSID as long as you know its SSID (and authentication secrets).

For information on connecting to a hidden wireless network, refer to *Section 6.3.2, "Connecting to a Hidden Wireless Network"*.

Mode

Infrastructure — Set **Mode** to **Infrastructure** if you are connecting to a dedicated wireless access point or one built into a network device such as a router or a switch.

Ad-hoc — Set **Mode** to **Ad-hoc** if you are creating a peer-to-peer network for two or more mobile devices to communicate directly with each other. If you use **Ad-hoc** mode, referred to as *Independent Basic Service Set* (IBSS) in the 802.11 standard, you must ensure that the same **SSID** is set for all participating wireless devices, and that they are all communicating over the same channel.

BSSID

The Basic Service Set Identifier (BSSID) is the MAC address of the specific wireless access point you are connecting to when in **Infrastructure** mode. This field is blank by default, and you are able to connect to a wireless access point by **SSID** without having to specify its **BSSID**. If the BSSID is specified, it will force the system to associate to a specific access point only.

For ad-hoc networks, the **BSSID** is generated randomly by the mac80211 subsystem when the ad-hoc network is created. It is not displayed by **NetworkManager**

MAC address

Like an Ethernet Network Interface Card (NIC), a wireless adapter has a unique MAC address (Media Access Control; also known as a *hardware address*) that identifies it to the system. Running the **`ip addr`** command will show the MAC address associated with each interface. For example, in the following **`ip addr`** output, the MAC address for the **`wlan0`** interface (which is **`00:1c:bf:02:f8:70`**) immediately follows the **`link/ether`** keyword:

```
~]# ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 16436 qdisc noqueue state UNKNOWN
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UNKNOWN qlen
 1000
    link/ether 52:54:00:26:9e:f1 brd ff:ff:ff:ff:ff:ff
    inet 192.168.122.251/24 brd 192.168.122.255 scope global eth0
    inet6 fe80::5054:ff:fe26:9ef1/64 scope link
       valid_lft forever preferred_lft forever
3: wlan0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP qlen 1000
    link/ether 00:1c:bf:02:f8:70 brd ff:ff:ff:ff:ff:ff
    inet 10.200.130.67/24 brd 10.200.130.255 scope global wlan0
    inet6 fe80::21c:bfff:fe02:f870/64 scope link
       valid_lft forever preferred_lft forever
```

A single system could have one or more wireless network adapters connected to it. The **MAC address** field therefore allows you to associate a specific wireless adapter with a specific

connection (or connections). As mentioned, you can determine the MAC address using the **`ip addr`** command, and then copy and paste that value into the **MAC address** text-entry field.

MTU
The MTU (Maximum Transmission Unit) value represents the size in bytes of the largest packet that the connection will use to transmit. If set to a non-zero number, only packets of the specified size or smaller will be transmitted. Larger packets are broken up into multiple Ethernet frames. It is recommended to leave this setting on **automatic**.

Saving Your New (or Modified) Connection and Making Further Configurations

Once you have finished editing the wireless connection, click the **Apply** button and **NetworkManager** will immediately save your customized configuration. Given a correct configuration, you can successfully connect to your the modified connection by selecting it from the **NetworkManager** Notification Area applet. See *Section 6.2.1, "Connecting to a Network"* for details on selecting and connecting to a network.

You can further configure an existing connection by selecting it in the **Network Connections** window and clicking **Edit** to return to the **Editing** dialog.

Then, to configure:

- security authentication for the wireless connection, click the **Wireless Security** tab and proceed to *Section 6.4.2, "Configuring Wireless Security"*;
- IPv4 settings for the connection, click the **IPv4 Settings** tab and proceed to *Section 6.4.4, "Configuring IPv4 Settings"*; or,
- IPv6 settings for the connection, click the **IPv6 Settings** tab and proceed to *Section 6.4.5, "Configuring IPv6 Settings"*.

6.3.3. Establishing a Mobile Broadband Connection

You can use **NetworkManager**'s mobile broadband connection abilities to connect to the following *2G* and *3G* services:

- 2G — *GPRS* (*General Packet Radio Service*) or *EDGE* (*Enhanced Data Rates for GSM Evolution*)
- 3G — *UMTS* (*Universal Mobile Telecommunications System*) or *HSPA* (*High Speed Packet Access*)

Your computer must have a mobile broadband device (modem), which the system has discovered and recognized, in order to create the connection. Such a device may be built into your computer (as is the case on many notebooks and netbooks), or may be provided separately as internal or external hardware. Examples include PC card, USB Modem or Dongle, mobile or cellular telephone capable of acting as a modem.

Procedure 6.3. Adding a New Mobile Broadband Connection

You can configure a mobile broadband connection by opening the **Network Connections** window and selecting the **Mobile Broadband** tab.

1. Open the Network Connections window by running, as a normal user:

```
~]$ nm-connection-editor &
```

The **Network Connections** window appears.

2. Select the **Mobile Broadband** tab.
3. Click the **Add** button to open the **Set up a Mobile Broadband Connection** assistant.
4. Under **Create a connection for this mobile broadband device**, choose the 2G- or 3G-capable device you want to use with the connection. If the dropdown menu is inactive, this indicates that the system was unable to detect a device capable of mobile broadband. In this case, click **Cancel**, ensure that you do have a mobile broadband-capable device attached and recognized by the computer and then retry this procedure. Click the **Forward** button.
5. Select the country where your service provider is located from the list and click the **Forward** button.
6. Select your provider from the list or enter it manually. Click the **Forward** button.
7. Select your payment plan from the dropdown menu and confirm the *Access Point Name* (APN) is correct. Click the **Forward** button.
8. Review and confirm the settings and then click the **Apply** button.
9. Edit the mobile broadband-specific settings by referring to the *Configuring the Mobile Broadband Tab* description below .

Procedure 6.4. Editing an Existing Mobile Broadband Connection

Follow these steps to edit an existing mobile broadband connection.

1. Open the Network Connections window by running, as a normal user:

   ```
   ~]$ nm-connection-editor &
   ```

   The **Network Connections** window appears.
2. Select the **Mobile Broadband** tab.
3. Select the connection you wish to edit and click the **Edit** button.
4. Configure the connection name, auto-connect behavior, and availability settings.

   Three settings in the **Editing** dialog are common to all connection types:

   - **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the **Mobile Broadband** tab of the **Network Connections** window.
   - **Connect automatically** — Check this box if you want **NetworkManager** to auto-connect to this connection when it is available. Refer to *Section 6.2.3, "Connecting to a Network Automatically"* for more information.
   - **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to *Section 6.2.4, "User and System Connections"* for details.
5. Edit the mobile broadband-specific settings by referring to the *Configuring the Mobile Broadband Tab* description below .

Saving Your New (or Modified) Connection and Making Further Configurations

Once you have finished editing your mobile broadband connection, click the **Apply** button and **NetworkManager** will immediately save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the **NetworkManager** Notification Area applet. See *Section 6.2.1, "Connecting to a Network"* for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the **Network Connections** window and clicking **Edit** to return to the **Editing** dialog.

Then, to configure:

- Point-to-point settings for the connection, click the **PPP Settings** tab and proceed to *Section 6.4.3, "Configuring PPP (Point-to-Point) Settings"*;
- IPv4 settings for the connection, click the **IPv4 Settings** tab and proceed to *Section 6.4.4, "Configuring IPv4 Settings"*; or,
- IPv6 settings for the connection, click the **IPv6 Settings** tab and proceed to *Section 6.4.5, "Configuring IPv6 Settings"*.

Configuring the Mobile Broadband Tab

If you have already added a new mobile broadband connection using the assistant (refer to *Procedure 6.3, "Adding a New Mobile Broadband Connection"* for instructions), you can edit the **Mobile Broadband** tab to disable roaming if home network is not available, assign a network ID, or instruct **NetworkManager** to prefer a certain technology (such as 3G or 2G) when using the connection.

Number
The number that is dialed to establish a PPP connection with the GSM-based mobile broadband network. This field may be automatically populated during the initial installation of the broadband device. You can usually leave this field blank and enter the **APN** instead.

Username
Enter the username used to authenticate with the network. Some providers do not provide a username, or accept any username when connecting to the network.

Password
Enter the password used to authenticate with the network. Some providers do not provide a password, or accept any password.

APN
Enter the *Access Point Name* (APN) used to establish a connection with the GSM-based network. Entering the correct APN for a connection is important because it often determines:

- how the user is billed for their network usage; and/or
- whether the user has access to the Internet, an intranet, or a subnetwork.

Network ID
Entering a **Network ID** causes **NetworkManager** to force the device to register only to a specific network. This can be used to ensure the connection does not roam when it is not possible to control roaming directly.

Type

Any — The default value of **Any** leaves the modem to select the fastest network.

3G (UMTS/HSPA) — Force the connection to use only 3G network technologies.

2G (GPRS/EDGE) — Force the connection to use only 2G network technologies.

Prefer 3G (UMTS/HSPA) — First attempt to connect using a 3G technology such as HSPA or UMTS, and fall back to GPRS or EDGE only upon failure.

Prefer 2G (GPRS/EDGE) — First attempt to connect using a 2G technology such as GPRS or EDGE, and fall back to HSPA or UMTS only upon failure.

Allow roaming if home network is not available

Uncheck this box if you want **NetworkManager** to terminate the connection rather than transition from the home network to a roaming one, thereby avoiding possible roaming charges. If the box is checked, **NetworkManager** will attempt to maintain a good connection by transitioning from the home network to a roaming one, and vice versa.

PIN

If your device's *SIM* (*Subscriber Identity Module*) is locked with a *PIN* (*Personal Identification Number*), enter the PIN so that **NetworkManager** can unlock the device. **NetworkManager** must unlock the SIM if a PIN is required in order to use the device for any purpose.

6.3.4. Establishing a VPN Connection

Establishing an encrypted Virtual Private Network (VPN) enables you to communicate securely between your Local Area Network (LAN), and another, remote LAN. After successfully establishing a VPN connection, a VPN router or gateway performs the following actions upon the packets you transmit:

1. it adds an *Authentication Header* for routing and authentication purposes;
2. it encrypts the packet data; and,
3. it encloses the data with an Encapsulating Security Payload (ESP), which constitutes the decryption and handling instructions.

The receiving VPN router strips the header information, decrypts the data, and routes it to its intended destination (either a workstation or other node on a network). Using a network-to-network connection, the receiving node on the local network receives the packets already decrypted and ready for processing. The encryption/decryption process in a network-to-network VPN connection is therefore transparent to clients.

Because they employ several layers of authentication and encryption, VPNs are a secure and effective means of connecting multiple remote nodes to act as a unified intranet.

Procedure 6.5. Adding a New VPN Connection

1. You can configure a new VPN connection by opening the **Network** window and selecting the **VPN** menu entry.
2. Click on the **NetworkManager** applet icon in the Notification Area. Clicking on the **Network Settings** menu entry opens the **Network** window, from where you can view some basic network configuration information and initiate configuration tasks.
3. Click on the **VPN** menu entry followed by **Configure** and proceed to *Section 6.3.4, "Establishing a VPN Connection"*. If there is no VPN menu entry click on the plus sign at the bottom. A dialog box appears. Ensure the interface is set to VPN.



A VPN plug-in is required

The appropriate NetworkManager VPN plug-in for the VPN type you want to configure must be installed. (refer to *Section 4.2.4, "Installing Packages"* for more information on how to install new packages in Fedora 17).

4. Click the **Create** button to open the **Choose a VPN Connection Type** assistant.

5. Select the VPN protocol for the gateway you are connecting to from the dropdown menu. The VPN protocols available for selection in the dropdown menu corresponds to the NetworkManager VPN plug-ins installed. For example, if the *NetworkManager VPN plug-in for openswan*is installed then the IPsec based VPN will be selectable from the dropdown menu.

   After selecting the correct one, press the **Create...** button.

6. The **Editing VPN Connection *1*** window then appears. This window presents settings customized for the type of VPN connection you selected in *Step 5*.

You can configure an existing VPN connection by opening the **Network** window and selecting the **VPN** menu entry.

1. Click on the **NetworkManager** applet icon in the Notification Area and click **Network Settings**. The **Network** window appears.

2. Select the **VPN** menu entry.

3. Select the connection you wish to edit and click the **Configure** button.

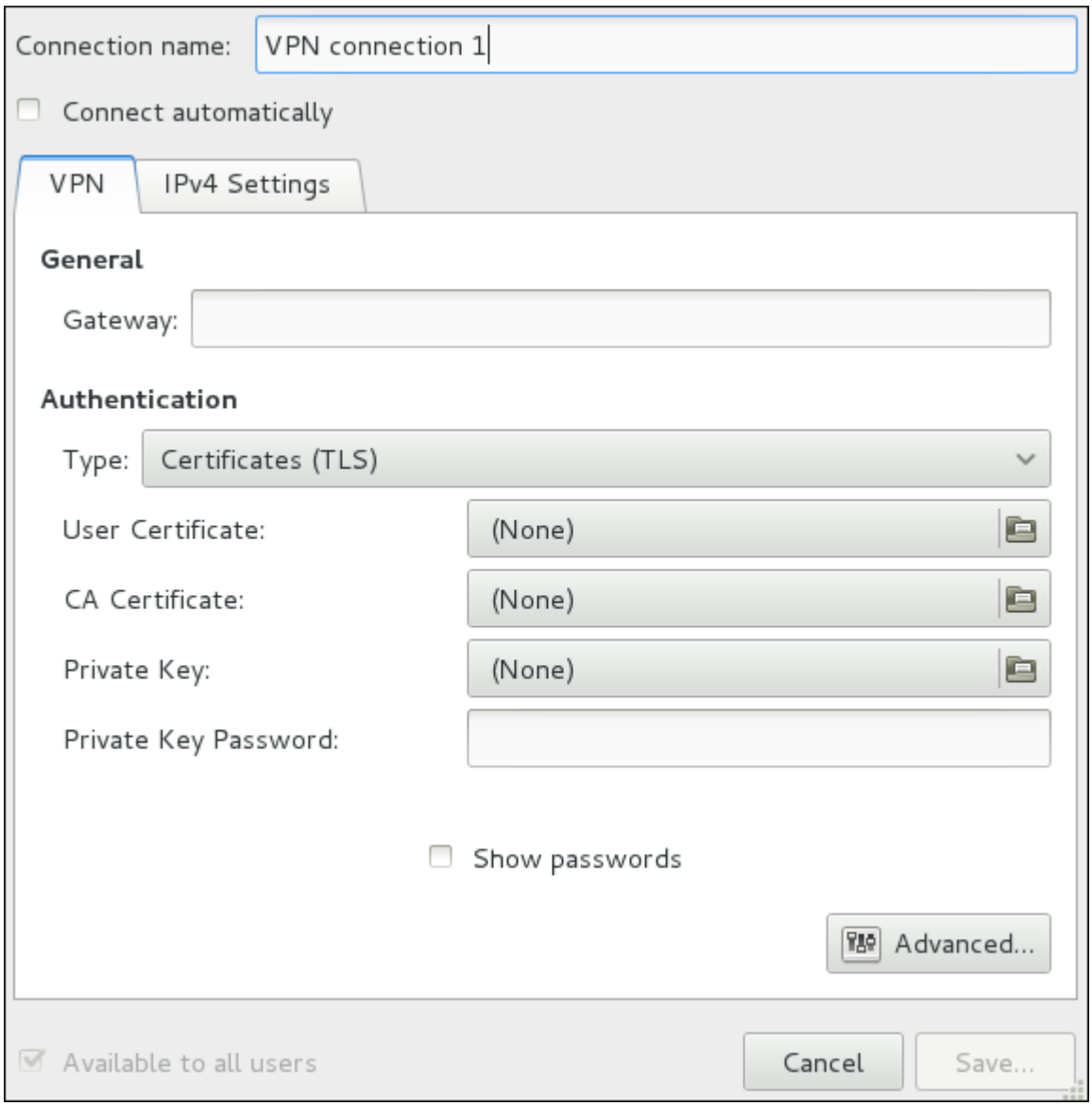


Figure 6.9. Editing the newly-created VPN connection 1.

Configuring the Connection Name, Auto-Connect Behavior, and Availability Settings

Three settings in the **Editing** dialog are common to all connection types:

- **Connection name** — Enter a descriptive name for your network connection. This name will be used to list this connection in the **VPN** tab of the **Network Connections** window.
- **Connect automatically** — Check this box if you want **NetworkManager** to auto-connect to this connection when it is available. Refer to *Section 6.2.3, "Connecting to a Network Automatically"* for more information.
- **Available to all users** — Check this box to create a connection available to all users on the system. Changing this setting may require root privileges. Refer to *Section 6.2.4, "User and System Connections"* for details.

Configuring the VPN Tab

Gateway
The name or IP address of the remote VPN gateway.

Group name
The name of a VPN group configured on the remote gateway.

User password
If required, enter the password used to authenticate with the VPN.

Group password
If required, enter the password used to authenticate with the VPN.

User name
If required, enter the username used to authenticate with the VPN.

Phase1 Algorithms
If required, enter the algorithms to be used to authenticate and set up an encrypted channel.

Phase2 Algorithms
If required, enter the algorithms to be used for the IPsec negotiations.

Domain
If required, enter the Domain Name.

NAT traversal
Cisco UDP (default) — IPsec over UDP.

NAT-T — ESP encapsulation and IKE extensions are used to handle NAT Traversal.

Disabled — No special NAT measures required.

Disable Dead Peer Detection — Disable the sending of probes to the remote gateway or endpoint.

Saving Your New (or Modified) Connection and Making Further Configurations

Once you have finished editing your new VPN connection, click the **Apply** button and **NetworkManager** will immediately save your customized configuration. Given a correct configuration, you can connect to your new or customized connection by selecting it from the **NetworkManager** Notification Area applet. See *Section 6.2.1, "Connecting to a Network"* for information on using your new or altered connection.

You can further configure an existing connection by selecting it in the **Network Connections** window and clicking **Edit** to return to the **Editing** dialog.

Then, to configure:

- IPv4 settings for the connection, click the **IPv4 Settings** tab and proceed to *Section 6.4.4, "Configuring IPv4 Settings"*.

6.3.5. Establishing a DSL Connection

Open the Network Connections window by running, as a normal user:

```
~]$ nm-connection-editor &
```

Select the DSL tab and click **Add**.

Username
Enter the username used to authenticate with the service provider.

Service
Leave blank unless otherwise directed.

Password
Enter the password supplied by the service provider.

6.3.6. Establishing Routes



Figure 6.10. Configuring static network routes

Addresses

Address — The IP address of a network, sub-net or host.

Netmask — The netmask or prefix length of the IP address just entered.

Gateway — The IP address of the gateway leading to the network, sub-net or host.

Metric — A network cost, that is to say a preference value to give to this route. Lower values will be preferred over higher values.

Ignore automatically obtained routes
Select this check box to only use manually entered routes for the VPN tunnel.

Use this connection only for resources on its network
Select this checkbox to prevent the VPN from becoming the default route. Then only the specific routes sent by the VPN server (or routes entered here manually) will be routed over the VPN tunnel.

6.4. Configuring Connection Settings

6.4.1. Configuring 802.1x Security

802.1x security is the name of the IEEE standard for port-based Network Access Control (PNAC). Simply put, 802.1x security is a way of defining a *logical network* out of a physical one. All clients who want to join the logical network must authenticate with the server (a router, for example) using the correct 802.1x authentication method.

802.1x security is most often associated with securing wireless networks (WLANs), but can also be used to prevent intruders with physical access to the network (LAN) from gaining entry. In the past, DHCP servers were configured not to lease IP addresses to unauthorized users, but for various reasons this practice is both impractical and insecure, and thus is no longer recommended. Instead, 802.1x security is used to ensure a logically-secure network through port-based authentication.

802.1x provides a framework for WLAN and LAN access control and serves as an envelope for carrying one of the Extensible Authentication Protocol (EAP) types. An EAP type is a protocol that defines how WLAN security is achieved on the network.

You can configure 802.1x security for a wired or wireless connection type by opening the **Network Connections** window (refer to *Section 6.2.2, "Configuring New and Editing Existing Connections"*) and following the applicable procedure:

Procedure 6.6. For a wired connection...

1. Select the **Wired** tab.
2. Either click on **Add** to add a new network connection for which you want to configure 802.1x security, or select an existing connection and click **Edit**.
3. Then select the **802.1x Security** tab and check the **Use 802.1x security for this connection** checkbox to enable settings configuration.
4. Proceed to *Section 6.4.1.1, "Configuring TLS (Transport Layer Security) Settings"*

Procedure 6.7. For a wireless connection...

1. Select the **Wireless** tab.
2. Either click on **Add** to add a new network connection for which you want to configure 802.1x security, or select an existing connection and click **Edit**.
3. Then click the **Security** dropdown and choose one of the following security methods: **LEAP**, **Dynamic WEP (802.1x)**, or **WPA & WPA2 Enterprise**.
4. Refer to *Section 6.4.1.1, "Configuring TLS (Transport Layer Security) Settings"* for descriptions of which EAP types correspond to your selection in the **Security** dropdown.

6.4.1.1. Configuring TLS (Transport Layer Security) Settings

With Transport Layer Security, the client and server mutually authenticate using the TLS protocol. The server demonstrates that it holds a digital certificate, the client proves its own identity using its client-side certificate, and key information is exchanged. Once authentication is complete, the TLS tunnel is no longer used. Instead, the client and server use the exchanged keys to encrypt data using AES, TKIP or WEP.

The fact that certificates must be distributed to all clients who want to authenticate means that the EAP-TLS authentication method is very strong, but also more complicated to set up. Using TLS security requires the overhead of a public key infrastructure (PKI) to manage certificates. The benefit of using TLS security is that a compromised password does not allow access to the (W)LAN: an intruder must also have access to the authenticating client's private key.

Network Manger does not determine the version of TLS supported. Network Manager gathers the parameters entered by the user and passes them to the daemon, wpa_supplicant, that handles the procedure. It, in turn, uses OpenSSL to establish the TLS tunnel. OpenSSL itself negotiates the SSL/TLS protocol version. It uses the highest version both ends support.

Identity
Identity string for EAP authentication methods, such as a username or login name.

User certificate
Click to browse for, and select, a user's certificate.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

Private key
Click to browse for, and select, a user's private key file.

Private key password
Enter the user password corresponding to the user's private key.

6.4.1.2. Configuring Tunneled TLS Settings

Anonymous identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

Inner authentication
PAP — Password Authentication Protocol.

MSCHAP — Challenge Handshake Authentication Protocol.

MSCHAPv2 — Microsoft Challenge Handshake Authentication Protocol version 2.

CHAP — Challenge Handshake Authentication Protocol.

Username
Enter the username to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

6.4.1.3. Configuring Protected EAP (PEAP) Settings

Anonymous Identity
This value is used as the unencrypted identity.

CA certificate
Click to browse for, and select, a Certificate Authority's certificate.

PEAP version
The version of Protected EAP to use. Automatic, 0 or 1.

Inner authentication
MSCHAPv2 — Microsoft Challenge Handshake Authentication Protocol version 2.

MD5 — Message Digest 5, a cryptographic hash function.

GTC — Generic Token Card.

Username
Enter the username to be used in the authentication process.

Password
Enter the password to be used in the authentication process.

6.4.2. Configuring Wireless Security

Security
None — Do not encrypt the Wi-Fi connection.

WEP 40/128-bit Key — Wired Equivalent Privacy (WEP), from the IEEE 802.11 standard. Uses a single pre-shared key (PSK).

WEP 128-bit Passphrase — An MD5 hash of the passphrase will be used to derive a WEP key.

LEAP — Lightweight Extensible Authentication Protocol, from Cisco Systems.

Dynamic WEP (802.1x) — WEP keys are changed dynamically.

WPA & WPA2 Personal — Wi-Fi Protected Access (WPA), from the draft IEEE 802.11i standard. A replacement for WEP. Wi-Fi Protected Access II (WPA2), from the 802.11i-2004 standard. Personal mode uses a pre-shared key (WPA-PSK).

WPA & WPA2 Enterprise — WPA for use with a RADUIS authentication server to provide IEEE 802.1x network access control.

Password
Enter the password to be used in the authentication process.

6.4.3. Configuring PPP (Point-to-Point) Settings

Configure Methods

Use point-to-point encryption (MPPE)
Microsoft Point-To-Point Encryption protocol (RFC 3078).

Allow BSD data compression
PPP BSD Compression Protocol (RFC 1977).

Allow Deflate data compression
PPP Deflate Protocol (RFC 1979).

Use TCP header compression
Compressing TCP/IP Headers for Low-Speed Serial Links (RFC 1144).

Send PPP echo packets
LCP Echo-Request and Echo-Reply Codes for loopback tests (RFC 1661).

6.4.4. Configuring IPv4 Settings

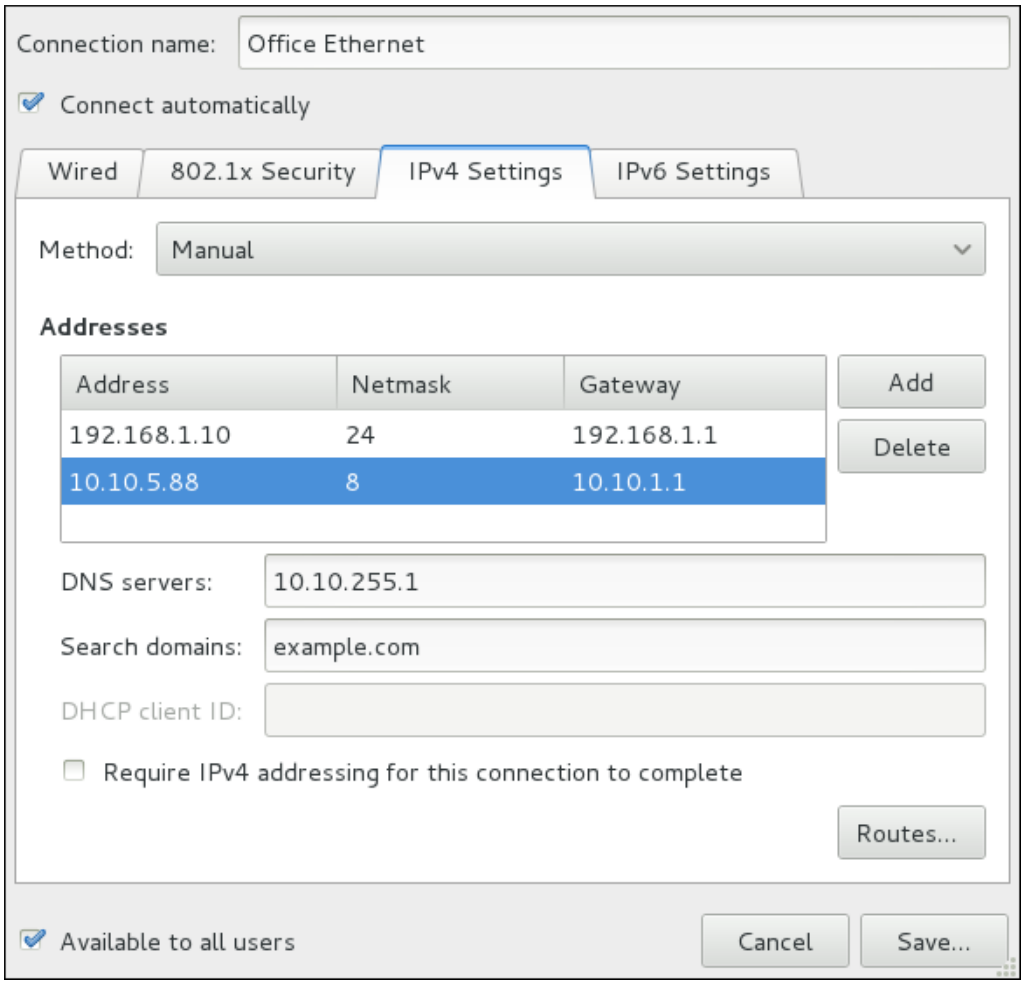


Figure 6.11. Editing the IPv4 Settings Tab

The **IPv4 Settings** tab allows you to configure the method by which you connect to the Internet and enter IP address, route, and DNS information as required. The **IPv4 Settings** tab is available when you create and modify one of the following connection types: wired, wireless, mobile broadband, VPN or DSL.

If you are using DHCP to obtain a dynamic IP address from a DHCP server, you can simply set **Method** to **Automatic (DHCP)**.

Setting the Method

Available IPv4 Methods by Connection Type

When you click the **Method** dropdown menu, depending on the type of connection you are configuring, you are able to select one of the following IPv4 connection methods. All of the methods are listed here according to which connection type or types they are associated with.

Method

Automatic (DHCP) — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses. You do not need to fill in the **DHCP client ID** field.

Automatic (DHCP) addresses only — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

Link-Local Only — Choose this option if the network you are connecting to does not have a DHCP server and you do not want to assign IP addresses manually. Random addresses will be selected as per RFC 3927.

Shared to other computers — Choose this option if the interface you are configuring is for sharing an Internet or WAN connection.

Wired, Wireless and DSL Connection Methods

Manual — Choose this option if the network you are connecting to does not have a DHCP server and you want to assign IP addresses manually.

Mobile Broadband Connection Methods

Automatic (PPP) — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.

Automatic (PPP) addresses only — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

VPN Connection Methods

Automatic (VPN) — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.

Automatic (VPN) addresses only — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

DSL Connection Methods

Automatic (PPPoE) — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.

Automatic (PPPoE) addresses only — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

6.4.5. Configuring IPv6 Settings

Method

Ignore — Choose this option if you want to disable IPv6 settings.

Automatic — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses.

Automatic, addresses only — Choose this option if the network you are connecting to uses a DHCP server to assign IP addresses but you want to assign DNS servers manually.

Manual — Choose this option if the network you are connecting to does not have a DHCP server and you want to assign IP addresses manually.

Link-Local Only — Choose this option if the network you are connecting to does not have a DHCP server and you do not want to assign IP addresses manually. Random addresses will be selected as per RFC 4862.

Shared to other computers — Choose this option if the interface you are configuring is for sharing an Internet or WAN connection.

Addresses

DNS servers — Enter a comma separated list of DNS servers.

Search domains — Enter a comma separated list of domain controllers.

6.5. NetworkManager Architecture

See *http://live.gnome.org/NetworkManagerConfiguration*

Network Interfaces

Under Fedora, all network communications occur between configured software *interfaces* and *physical networking devices* connected to the system.

The configuration files for network interfaces are located in the **/etc/sysconfig/network-scripts/** directory. The scripts used to activate and deactivate these network interfaces are also located here. Although the number and type of interface files can differ from system to system, there are three categories of files that exist in this directory:

1. *Interface configuration files*
2. *Interface control scripts*
3. *Network function files*

The files in each of these categories work together to enable various network devices.

This chapter explores the relationship between these files and how they are used.

7.1. Network Configuration Files

Before delving into the interface configuration files, let us first itemize the primary configuration files used in network configuration. Understanding the role these files play in setting up the network stack can be helpful when customizing a Fedora system.

The primary network configuration files are as follows:

/etc/hosts
The main purpose of this file is to resolve hostnames that cannot be resolved any other way. It can also be used to resolve hostnames on small networks with no DNS server. Regardless of the type of network the computer is on, this file should contain a line specifying the IP address of the loopback device (`127.0.0.1`) as `localhost.localdomain`. For more information, refer to the **hosts**(5) manual page.

/etc/resolv.conf
This file specifies the IP addresses of DNS servers and the search domain. Unless configured to do otherwise, the network initialization scripts populate this file. For more information about this file, refer to the **resolv.conf**(5) manual page.

/etc/sysconfig/network
This file specifies routing and host information for all network interfaces. For more information about this file and the directives it accepts, refer to *Section D.1.13, " /etc/sysconfig/network "*.

/etc/sysconfig/network-scripts/ifcfg-*interface-name*
For each network interface, there is a corresponding interface configuration script. Each of these files provide information specific to a particular network interface. Refer to *Section 7.2, "Interface Configuration Files"* for more information on this type of file and the directives it accepts.



Network interface names

Network interface names may be different on different hardware types. Refer to *Appendix A, Consistent Network Device Naming* for more information.



The /etc/sysconfig/networking/ directory

The **/etc/sysconfig/networking/** directory is used by the now deprecated **Network Administration Tool** (**system-config-network**). Its contents should **not** be edited manually. Using only one method for network configuration is strongly encouraged, due to the risk of configuration deletion. For more information about configuring network interfaces using graphical configuration tools, refer to *Chapter 6, NetworkManager*.

7.2. Interface Configuration Files

Interface configuration files control the software interfaces for individual network devices. As the system boots, it uses these files to determine what interfaces to bring up and how to configure them. These files are usually named **ifcfg-*name*** , where *name* refers to the name of the device that the configuration file controls.

7.2.1. Ethernet Interfaces

One of the most common interface files is **/etc/sysconfig/network-scripts/ifcfg-eth0**, which controls the first Ethernet *network interface card* or NIC in the system. In a system with multiple NICs, there are multiple **ifcfg-eth*X*** files (where *X* is a unique number corresponding to a specific interface). Because each device has its own configuration file, an administrator can control how each interface functions individually.

The following is a sample **ifcfg-eth0** file for a system using a fixed IP address:

```
DEVICE=eth0
BOOTPROTO=none
ONBOOT=yes
NETMASK=255.255.255.0
IPADDR=10.0.1.27
USERCTL=no
```

The values required in an interface configuration file can change based on other values. For example, the **ifcfg-eth0** file for an interface using DHCP looks different because IP information is provided by the DHCP server:

```
DEVICE=eth0
BOOTPROTO=dhcp
ONBOOT=yes
```

NetworkManager is graphical configuration tool which provides an easy way to make changes to the various network interface configuration files (refer to *Chapter 6, NetworkManager* for detailed instructions on using this tool).

However, it is also possible to manually edit the configuration files for a given network interface.

Below is a listing of the configurable parameters in an Ethernet interface configuration file:

BONDING_OPTS=*parameters*
sets the configuration parameters for the bonding device, and is used in **/etc/sysconfig/network-scripts/ifcfg-bond*N*** (see *Section 7.2.2, "Channel Bonding Interfaces"*). These parameters are identical to those used for bonding devices in **/sys/class/net/*bonding_device*/bonding**, and the module parameters for the bonding driver as described in ***bonding*** *Module Directives*.

This configuration method is used so that multiple bonding devices can have different configurations. It is highly recommended to place all of your bonding options after the **BONDING_OPTS** directive in **ifcfg-*name***. Do *not* specify options for the bonding device in **/etc/modprobe.d/*bonding*.conf**, or in the deprecated **/etc/modprobe.conf** file.

BOOTPROTO=*protocol*
where *protocol* is one of the following:

- **none** — No boot-time protocol should be used.
- **bootp** — The BOOTP protocol should be used.
- **dhcp** — The DHCP protocol should be used.

BROADCAST=*address*
where *address* is the broadcast address. This directive is deprecated, as the value is calculated automatically with **ipcalc**.

DEVICE=*name*
where *name* is the name of the physical device (except for dynamically-allocated PPP devices where it is the *logical name*).

DHCP_HOSTNAME=*name*
where *name* is a short hostname to be sent to the DHCP server. Use this option only if the DHCP server requires the client to specify a hostname before receiving an IP address.

DNS*{1,2}*=*address*
where *address* is a name server address to be placed in **/etc/resolv.conf** if the **PEERDNS** directive is set to **yes**.

ETHTOOL_OPTS=*options*
where *options* are any device-specific options supported by **ethtool**. For example, if you wanted to force 100Mb, full duplex:

```
ETHTOOL_OPTS="autoneg off speed 100 duplex full"
```

Instead of a custom initscript, use **ETHTOOL_OPTS** to set the interface speed and duplex settings. Custom initscripts run outside of the network init script lead to unpredictable results during a post-boot network service restart.



Set “autoneg off” before changing speed or duplex settings

Changing speed or duplex settings almost always requires disabling autonegotiation with the **autoneg off** option. This option needs to be stated first, as the option entries are order-dependent.

HOTPLUG=*answer*
where *answer* is one of the following:

- **yes** — This device should be activated when it is hot-plugged (this is the default option).
- **no** — This device should *not* be activated when it is hot-plugged.

The **HOTPLUG=no** option can be used to prevent a channel bonding interface from being activated when a bonding kernel module is loaded.

Refer to *Section 7.2.2, “Channel Bonding Interfaces”* for more information about channel bonding interfaces.

HWADDR=*MAC-address*
where *MAC-address* is the hardware address of the Ethernet device in the form *AA:BB:CC:DD:EE:FF*. This directive must be used in machines containing more than one NIC to ensure that the interfaces are assigned the correct device names regardless of the configured load order for each NIC's module. This directive should **not** be used in conjunction with **MACADDR**.



Note

Persistent device names are now handled by **/etc/udev/rules.d/70-persistent-net.rules**.

IPADDR=*address*
where *address* is the IP address.

LINKDELAY=*time*
where *time* is the number of seconds to wait for link negotiation before configuring the device.

MACADDR=*MAC-address*
where *MAC-address* is the hardware address of the Ethernet device in the form *AA:BB:CC:DD:EE:FF*.

This directive is used to assign a MAC address to an interface, overriding the one assigned to the physical NIC. This directive should **not** be used in conjunction with the **HWADDR** directive.

MASTER=*bond-interface*
where *bond-interface* is the channel bonding interface to which the Ethernet interface is linked.

This directive is used in conjunction with the **SLAVE** directive.

Refer to *Section 7.2.2, "Channel Bonding Interfaces"* for more information about channel bonding interfaces.

NETMASK=*mask*
where *mask* is the netmask value.

NETWORK=*address*
where *address* is the network address. This directive is deprecated, as the value is calculated automatically with **ipcalc**.

NM_CONTROLLED=*answer*
where *answer* is one of the following:

- **yes** — NetworkManager is permitted to configure this device.This is the default behavior and can be omitted.
- **no** — NetworkManager is not permitted to configure this device.

ONBOOT=*answer*
where *answer* is one of the following:

- **yes** — This device should be activated at boot-time.
- **no** — This device should not be activated at boot-time.

PEERDNS=*answer*
where *answer* is one of the following:

- **yes** — Modify **/etc/resolv.conf** if the DNS directive is set. If using DHCP, then **yes** is the default.
- **no** — Do not modify **/etc/resolv.conf**.

SLAVE=*answer*
where *answer* is one of the following:

- **yes** — This device is controlled by the channel bonding interface specified in the **MASTER** directive.
- **no** — This device is *not* controlled by the channel bonding interface specified in the **MASTER** directive.

This directive is used in conjunction with the **MASTER** directive.

Refer to *Section 7.2.2, "Channel Bonding Interfaces"* for more about channel bonding interfaces.

SRCADDR=*address*
where *address* is the specified source IP address for outgoing packets.

USERCTL=*answer*
where *answer* is one of the following:

- **yes** — Non-root users are allowed to control this device.
- **no** — Non-root users are not allowed to control this device.

7.2.2. Channel Bonding Interfaces

Fedora allows administrators to bind multiple network interfaces together into a single channel using the **bonding** kernel module and a special network interface called a *channel bonding interface*. Channel bonding enables two or more network interfaces to act as one, simultaneously increasing the bandwidth and providing redundancy.

To create a channel bonding interface, create a file in the **/etc/sysconfig/network-scripts/** directory called **ifcfg-bond*N***, replacing *N* with the number for the interface, such as **0**.

The contents of the file can be identical to whatever type of interface is getting bonded, such as an Ethernet interface. The only difference is that the **DEVICE** directive is **bond*N***, replacing *N* with the number for the interface.

The following is a sample channel bonding configuration file:

> Example 7.1. Sample ifcfg-bond0 interface configuration file
>
> ```
> DEVICE=bond0
> IPADDR=192.168.1.1
> NETMASK=255.255.255.0
> ONBOOT=yes
> BOOTPROTO=none
> USERCTL=no
> BONDING_OPTS="bonding parameters separated by spaces"
> ```

After the channel bonding interface is created, the network interfaces to be bound together must be configured by adding the **MASTER** and **SLAVE** directives to their configuration files. The configuration files for each of the channel-bonded interfaces can be nearly identical.

For example, if two Ethernet interfaces are being channel bonded, both `eth0` and `eth1` may look like the following example:

```
DEVICE=ethN
BOOTPROTO=none
ONBOOT=yes
MASTER=bond0
SLAVE=yes
USERCTL=no
```

In this example, replace *N* with the numerical value for the interface.

For a channel bonding interface to be valid, the kernel module must be loaded. To ensure that the module is loaded when the channel bonding interface is brought up, create a new file as root named ***bonding*.conf** in the **/etc/modprobe.d/** directory. Note that you can name this file anything you like as long as it ends with a **.conf** extension. Insert the following line in this new file:

```
alias bondN bonding
```

Replace *N* with the interface number, such as **0**. For each configured channel bonding interface, there must be a corresponding entry in your new **/etc/modprobe.d/*bonding*.conf** file.



Put all bonding module parameters in ifcfg-bondN files

Parameters for the bonding kernel module must be specified as a space-separated list in the **BONDING_OPTS="*bonding parameters*"** directive in the **ifcfg-bond*N*** interface file. Do *not* specify options for the bonding device in **/etc/modprobe.d/*bonding*.conf**, or in the deprecated **/etc/modprobe.conf** file. For further instructions and advice on configuring the bonding module and to view the list of bonding parameters, refer to *Section 22.7.2, "Using Channel Bonding"*.

7.2.3. Network Bridge

A network bridge is a Link Layer device which forwards traffic between networks based on MAC addresses and is therefore also referred to as a Layer 2 device. It makes forwarding decisions based on tables of MAC addresses which it builds by learning what hosts are connected to each network. A software bridge can be used within a Linux host in order to emulate a hardware bridge, for example in virtualization applications for sharing a NIC with one or more virtual NICs. This case will be illustrated here as an example.

To create a network bridge, create a file in the **/etc/sysconfig/network-scripts/** directory called **ifcfg-br*N***, replacing *N* with the number for the interface, such as **0**.

The contents of the file is similar to whatever type of interface is getting bridged to, such as an Ethernet interface. The differences in this example are as follows:

- The **DEVICE** directive is given an interface name as its argument in the format **br*N***, where *N* is replaced with the number of the interface.
- The **TYPE** directive is given an argument **Bridge** or **Ethernet**. This directive determines the device type and the argument is case sensitive.
- The bridge interface configuration file now has the IP address and the physical interface has only a MAC address.
- An extra directive, **DELAY=0**, is added to prevent the bridge from waiting while it monitors traffic, learns where hosts are located, and builds a table of MAC addresses on which to base its filtering decisions. The default delay of 30 seconds is not needed if no routing loops are possible.
- The **NM_CONTROLLED=no** should be added to the Ethernet interface to prevent **NetworkManager** from altering the file. It can also be added to the bridge configuration file in case future versions of **NetworkManager** support bridge configuration.

The following is a sample bridge interface configuration file using a static IP address:

Example 7.2. Sample ifcfg-br0 interface configuration file

```
DEVICE=br0
TYPE=Bridge
IPADDR=192.168.1.1
NETMASK=255.255.255.0
ONBOOT=yes
BOOTPROTO=static
NM_CONTROLLED=no
DELAY=0
```

To complete the bridge another interface is created, or an existing interface is modified, and pointed to the bridge interface. The following is a sample Ethernet interface configuration file pointing to a bridge interface. Configure your physical interface in **/etc/sysconfig/network-scripts/ifcfg-eth*X***, where *X* is a unique number corresponding to a specific interface, as follows:

Example 7.3. Sample ifcfg-ethX interface configuration file

```
DEVICE=ethX
TYPE=Ethernet
HWADDR=AA:BB:CC:DD:EE:FF
BOOTPROTO=none
ONBOOT=yes
NM_CONTROLLED=no
BRIDGE=br0
```



Note

For the **DEVICE** directive, almost any interface name could be used as it does not determine the device type. Other commonly used names include **tap**, **dummy** and **bond** for example. **TYPE=Ethernet** is not strictly required. If the **TYPE** directive is not set, the device is treated as an Ethernet device (unless it's name explicitly matches a different interface configuration file.)

You can refer to *Section 7.2, "Interface Configuration Files"* for a review of the directives and options used in network interface config files.



Warning

If you are configuring bridging on a remote host, and you are connected to that host over the physical NIC you are configuring, please consider the implications of losing connectivity before proceeding. You will lose connectivity when restarting the service and may not be able to regain connectivity if any errors have been made. Console, or out-of-band access is advised.

Restart the networking service, in order for the changes to take effect by running as `root`:

```
systemctl restart network.service
```

An example of a network bridge formed from two or more bonded Ethernet interfaces will now be given as this is another common application in a virtualization environment. If you are not very familiar with the configuration files for bonded interfaces then please refer to *Section 7.2.2, "Channel Bonding Interfaces"*

Create or edit two or more Ethernet interface configuration files, which are to be bonded, as follows:

```
DEVICE=ethX
TYPE=Ethernet
USERCTL=no
SLAVE=yes
MASTER=bond0
```

```
BOOTPROTO=none
HWADDR=AA:BB:CC:DD:EE:FF
NM_CONTROLLED=no
```

Note

Using `eth`*X* as the interface name is common practice but almost any name could be used. Names such as **`tap`**, **`dummy`** and **`bond`** are commonly used.

Create or edit one interface configuration file, **`/etc/sysconfig/network-scripts/ifcfg-bond0`**, as follows:

```
DEVICE=bond0
ONBOOT=yes
BONDING_OPTS='mode=1 miimon=100'
BRIDGE=brbond0
NM_CONTROLLED=no
```

For further instructions and advice on configuring the bonding module and to view the list of bonding parameters, refer to *Section 22.7.2, "Using Channel Bonding"*.

Create or edit one interface configuration file, **`/etc/sysconfig/network-scripts/ifcfg-brbond0`**, as follows:

```
DEVICE=brbond0
ONBOOT=yes
TYPE=Bridge
IPADDR=192.168.1.1
NETMASK=255.255.255.0
NM_CONTROLLED=no
```

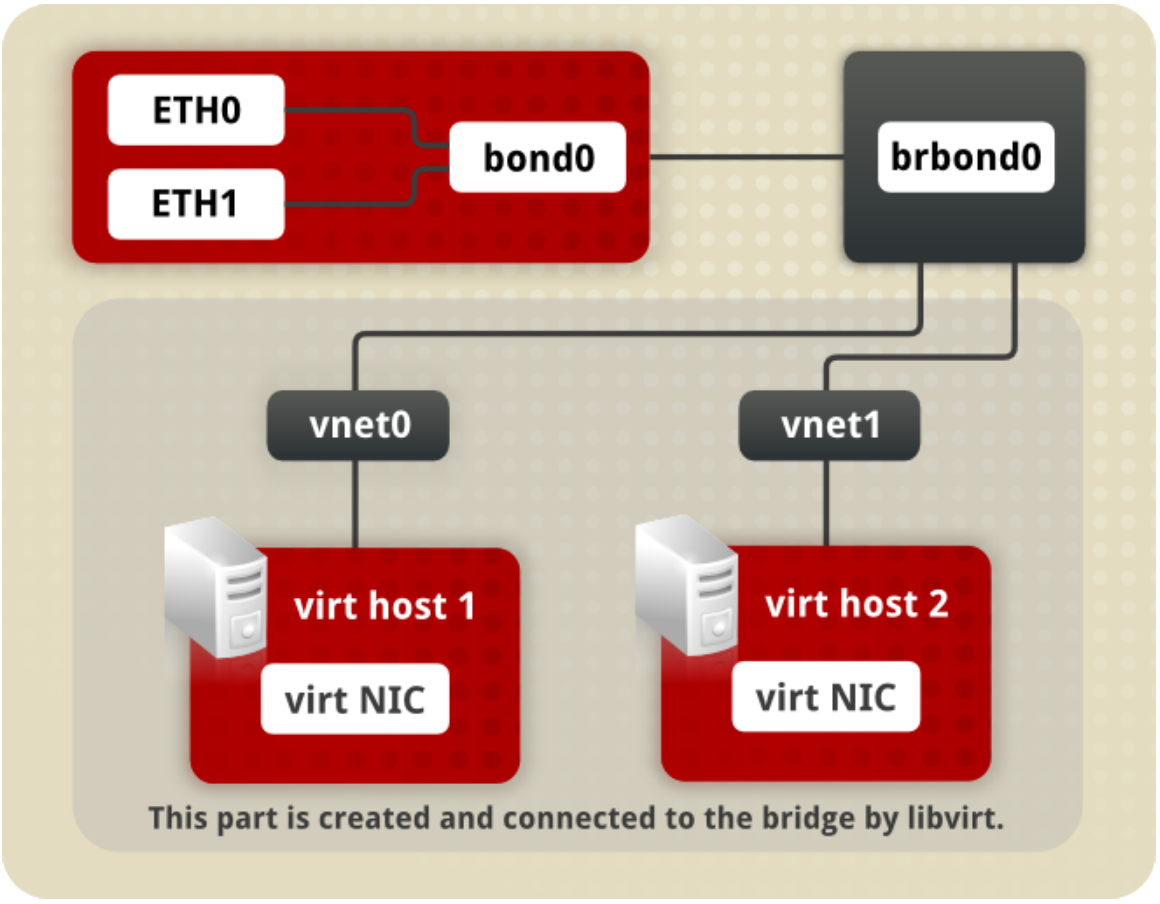


Figure 7.1. A network bridge consisting of two bonded Ethernet interfaces.

We now have two or more interface configuration files with the **`MASTER=bond0`** directive. These point to the configuration file named **`/etc/sysconfig/network-scripts/ifcfg-bond0`**, which contains the **`DEVICE=bond0`** directive. This **`ifcfg-bond0`** in turn points to the **`/etc/sysconfig/network-scripts/ifcfg-brbond0`** configuration file, which contains the IP address, and acts as an interface to the virtual networks inside the host.

Restart the networking service, in order for the changes to take effect by running as `root`:

```
systemctl restart network.service
```

7.2.4. Setting Up 802.1q VLAN Tagging

1. Ensure that the module is loaded by entering the following command:

   ```
   lsmod | grep 8021q
   ```

2. If the module is not loaded, load it with the following command:

   ```
   modprobe 8021q
   ```

3. Configure your physical interface in **`/etc/sysconfig/network-scripts/ifcfg-eth`*`X`***, where *X* is a unique number corresponding to a specific interface, as follows:

```
DEVICE=ethX
TYPE=Ethernet
BOOTPROTO=none
ONBOOT=yes
```

4. Configure the VLAN interface configuration in **`/etc/sysconfig/network-scripts`**. The configuration filename should be the physical interface plus a **`.`** character plus the VLAN ID number. For example, if the VLAN ID is 192, and the physical interface is `eth0`, then the configuration filename should be **`ifcfg-eth0.192`**:

```
DEVICE=ethX.192
BOOTPROTO=static
ONBOOT=yes
IPADDR=192.168.1.1
NETMASK=255.255.255.0
USERCTL=no
NETWORK=192.168.1.0
VLAN=yes
```

   If there is a need to configure a second VLAN, with for example, VLAN ID 193, on the same interface, `eth0` , add a new file with the name **`eth0.193`** with the VLAN configuration details.

5. Restart the networking service, in order for the changes to take effect by running as `root`:

```
systemctl restart network.service
```

7.2.5. Alias and Clone Files

Two lesser-used types of interface configuration files are *alias* and *clone* files. As the **`ip`** command of the *iproute* package now supports assigning multiple address to the same interface it is no longer necessary to use this method of binding multiple addresses to the same interface.



Note

At the time of writing, **NetworkManager** does not detect IP aliases in **`ifcfg`** files. For example, if **`ifcfg-eth0`** and **`ifcfg-eth0:1`** files are present, **NetworkManager** creates two connections, which will cause confusion.

For new installations, users should select the **Manual** method on the IPv4 or IPv6 tab in **NetworkManager** to assign multiple IP address to the same interface. For more information on using this tool, refer to *Chapter 6, NetworkManager*.

Alias interface configuration files, which are used to bind multiple addresses to a single interface, use the **`ifcfg-`*`if-name`*`:`*`alias-value`** naming scheme.

For example, an **`ifcfg-eth0:0`** file could be configured to specify **`DEVICE=eth0:0`** and a static IP address of `10.0.0.2`, serving as an alias of an Ethernet interface already configured to receive its IP information via DHCP in **`ifcfg-eth0`**. Under this configuration, `eth0` is bound to a dynamic IP address, but the same physical network card can receive requests via the fixed, `10.0.0.2` IP address.



Warning

Alias interfaces do not support DHCP.

A clone interface configuration file should use the following naming convention: **ifcfg-*if-name-clone-name***. While an alias file allows multiple addresses for an existing interface, a clone file is used to specify additional options for an interface. For example, a standard DHCP Ethernet interface called `eth0`, may look similar to this:

```
DEVICE=eth0
ONBOOT=yes
BOOTPROTO=dhcp
```

Since the default value for the **USERCTL** directive is **no** if it is not specified, users cannot bring this interface up and down. To give users the ability to control the interface, create a clone by copying **ifcfg-eth0** to **ifcfg-eth0-user** and add the following line to **ifcfg-eth0-user**:

```
USERCTL=yes
```

This way a user can bring up the `eth0` interface using the **/sbin/ifup eth0-user** command because the configuration options from **ifcfg-eth0** and **ifcfg-eth0-user** are combined. While this is a very basic example, this method can be used with a variety of options and interfaces.

It is no longer possible to create alias and clone interface configuration files using a graphical tool. However, as explained at the beginning of this section, it is no longer necessary to use this method as it is now possible to directly assign multiple IP address to the same interface. For new installations, users should select the **Manual** method on the IPv4 or IPv6 tab in **NetworkManager** to assign multiple IP address to the same interface. For more information on using this tool, refer to *Chapter 6, NetworkManager*.

7.2.6. Dialup Interfaces

If you are connecting to the Internet via a dialup connection, a configuration file is necessary for the interface.

PPP interface files are named using the following format:

ifcfg-ppp*X*

where *X* is a unique number corresponding to a specific interface.

The PPP interface configuration file is created automatically when **wvdial**, the **Network Administration Tool** or **Kppp** is used to create a dialup account. It is also possible to create and edit this file manually.

The following is a typical **ifcfg-ppp0** file:

```
DEVICE=ppp0
NAME=test
WVDIALSECT=test
MODEMPORT=/dev/modem
LINESPEED=115200
```

```
PAPNAME=test
USERCTL=true
ONBOOT=no
PERSIST=no
DEFROUTE=yes
PEERDNS=yes
DEMAND=no
IDLETIMEOUT=600
```

Serial Line Internet Protocol (SLIP) is another dialup interface, although it is used less frequently. SLIP files have interface configuration file names such as **ifcfg-sl0**.

Other options that may be used in these files include:

DEFROUTE=*answer*
where *answer* is one of the following:

- **yes** — Set this interface as the default route.
- **no** — Do not set this interface as the default route.

DEMAND=*answer*
where *answer* is one of the following:

- **yes** — This interface allows **pppd** to initiate a connection when someone attempts to use it.
- **no** — A connection must be manually established for this interface.

IDLETIMEOUT=*value*
where *value* is the number of seconds of idle activity before the interface disconnects itself.

INITSTRING=*string*
where *string* is the initialization string passed to the modem device. This option is primarily used in conjunction with SLIP interfaces.

LINESPEED=*value*
where *value* is the baud rate of the device. Possible standard values include **57600**, **38400**, **19200**, and **9600**.

MODEMPORT=*device*
where *device* is the name of the serial device that is used to establish the connection for the interface.

MTU=*value*
where *value* is the *Maximum Transfer Unit* (MTU) setting for the interface. The MTU refers to the largest number of bytes of data a frame can carry, not counting its header information. In some dialup situations, setting this to a value of **576** results in fewer packets dropped and a slight improvement to the throughput for a connection.

NAME=*name*
where *name* is the reference to the title given to a collection of dialup connection configurations.

PAPNAME=*name*
where *name* is the username given during the *Password Authentication Protocol* (PAP) exchange that occurs to allow connections to a remote system.

PERSIST=*answer*
where *answer* is one of the following:

- **yes** — This interface should be kept active at all times, even if deactivated after a modem hang up.
- **no** — This interface should not be kept active at all times.

REMIP=*address*
where *address* is the IP address of the remote system. This is usually left unspecified.

WVDIALSECT=*name*
where *name* associates this interface with a dialer configuration in **/etc/wvdial.conf**. This file contains the phone number to be dialed and other important information for the interface.

7.2.7. Other Interfaces

Other common interface configuration files include the following:

ifcfg-lo
A local *loopback interface* is often used in testing, as well as being used in a variety of applications that require an IP address pointing back to the same system. Any data sent to the loopback device is immediately returned to the host's network layer.



Do not manually edit the ifcfg-lo script

The loopback interface script, **/etc/sysconfig/network-scripts/ifcfg-lo**, should never be edited manually. Doing so can prevent the system from operating correctly.

ifcfg-irlan0
An *infrared interface* allows information between devices, such as a laptop and a printer, to flow over an infrared link. This works in a similar way to an Ethernet device except that it commonly occurs over a peer-to-peer connection.

ifcfg-plip0
A *Parallel Line Interface Protocol* (PLIP) connection works much the same way as an Ethernet device, except that it utilizes a parallel port.

7.3. Interface Control Scripts

The interface control scripts activate and deactivate system interfaces. There are two primary interface control scripts that call on control scripts located in the **/etc/sysconfig/network-scripts/** directory: **/sbin/ifdown** and **/sbin/ifup**.

The **ifup** and **ifdown** interface scripts are symbolic links to scripts in the **/sbin/** directory. When either of these scripts are called, they require the value of the interface to be specified, such as:

```
ifup eth0
```



Use the ifup and ifdown interface scripts

The **ifup** and **ifdown** interface scripts are the only scripts that the user should use to bring up and take down network interfaces.

The following scripts are described for reference purposes only.

Two files used to perform a variety of network initialization tasks during the process of bringing up a network interface are **/etc/rc.d/init.d/functions** and **/etc/sysconfig/network-scripts/network-functions**. Refer to *Section 7.5, "Network Function Files"* for more information.

After verifying that an interface has been specified and that the user executing the request is allowed to control the interface, the correct script brings the interface up or down. The following are common interface control scripts found within the **/etc/sysconfig/network-scripts/** directory:

ifup-aliases
Configures IP aliases from interface configuration files when more than one IP address is associated with an interface.

ifup-ippp and **ifdown-ippp**
Brings ISDN interfaces up and down.

ifup-ipv6 and **ifdown-ipv6**
Brings IPv6 interfaces up and down.

ifup-plip
Brings up a PLIP interface.

ifup-plusb
Brings up a USB interface for network connections.

ifup-post and **ifdown-post**
Contains commands to be executed after an interface is brought up or down.

ifup-ppp and **ifdown-ppp**
Brings a PPP interface up or down.

ifup-routes
Adds static routes for a device as its interface is brought up.

ifdown-sit and **ifup-sit**
Contains function calls related to bringing up and down an IPv6 tunnel within an IPv4 connection.

ifup-wireless
Brings up a wireless interface.



Be careful when removing or modifying network scripts!

Removing or modifying any scripts in the **/etc/sysconfig/network-scripts/** directory can cause interface connections to act irregularly or fail. Only advanced users should modify scripts related to a network interface.

The easiest way to manipulate all network scripts simultaneously is to use the **systemctl** command on the network service (**/etc/rc.d/init.d/network**), as illustrated by the following command:

```
systemctl action network.service
```

Here, *action* can be either **start**, **stop**, or **restart**.

To view a list of configured devices and currently active network interfaces, use the following command:

```
systemctl status network.service
```



Note

The older SysV service commands, such as “service network status” are considered deprecated but will still work. The SysV services can define their status in an arbitrary fashion so the output of the status command is not considered predictable over time. The SysV commands are retained for compatibility purposes. The **/sbin/service** utility will call **systemctl** when necessary.

7.4. Static Routes and the Default Gateway

Static routes are for traffic that must not, or should not, go through the default gateway. Routing is usually handled by routing devices and therefore it is often not necessary to configure static routes on Red Hat Enterprise Linux servers or clients. Exceptions include traffic that must pass through an encrypted VPN tunnel or traffic that should take a less costly route. The default gateway is for any and all traffic which is not destined for the local network and for which no preferred route is specified in the routing table. The default gateway is traditionally a dedicated network router.

Static Routes

Use the **ip route** command to display the IP routing table. If static routes are required, they can be added to the routing table by means of the **ip route add** command and removed using the **ip route del** command. To add a static route to a host address, that is to say to a single IP address, issue the following command as `root`:

```
ip route add X.X.X.X
```

where X.X.X.X is the IP address of the host in dotted decimal notation. To add a static route to a network, that is to say to an IP address representing a range of IP addresses, issue the following command as `root`:

```
ip route add X.X.X.X/Y
```

where X.X.X.X is the IP address of the network in dotted decimal notation and Y is the network prefix. The network prefix is the number of enabled bits in the subnet mask. This format of network address slash prefix length is referred to as CIDR notation.

Static route configuration is stored per-interface in a **/etc/sysconfig/network-scripts/route-*interface*** file. For example, static routes for the `eth0` interface would be stored in the **/etc/sysconfig/network-scripts/route-eth0** file. The **route-*interface*** file has two formats: IP command arguments and network/netmask directives. These are described below.

The Default Gateway

The default gateway is specified by means of the GATEWAY directive and can be specified either globally or in interface-specific configuration files. Specifying the default gateway globally has certain advantages especially if more than one network interface is present and it can make fault finding simpler if applied consistently. There is also the GATEWAYDEV directive, which is a global option. If multiple devices specify GATEWAY, and one interface uses the GATEWAYDEV directive, that directive will take precedence. This option is not recommend as it can have unexpected consequences if an interface goes down and it can complicate fault finding.

Global default gateway configuration is stored in the **/etc/sysconfig/network** file. This file specifies gateway and host information for all network interfaces. For more information about this file and the directives it accepts, refer to *Section D.1.13, " /etc/sysconfig/network "*.

IP Command Arguments Format

If required in a per-interface configuration file, define a default gateway on the first line. This is only required if the default gateway is not set via DHCP and is not set globally as mentioned above:

```
default via X.X.X.X dev interface
```

X.X.X.X is the IP address of the default gateway. The *interface* is the interface that is connected to, or can reach, the default gateway. The **dev** option can be omitted, it is optional.

Define a static route. Each line is parsed as an individual route:

```
X.X.X.X/Y via X.X.X.X dev interface
```

X.X.X.X/Y is the network address and netmask for the static route. *X.X.X.X* and *interface* are the IP address and interface for the default gateway respectively. The *X.X.X.X* address does not have to be the default gateway IP address. In most cases, *X.X.X.X* will be an IP address in a different subnet, and *interface* will be the interface that is connected to, or can reach, that subnet. Add as many static routes as required.

The following is a sample **route-eth0** file using the IP command arguments format. The default gateway is 192.168.0.1, interface eth0. The two static routes are for the 10.10.10.0/24 and 172.16.1.0/24 networks:

```
default via 192.168.0.1 dev eth0
10.10.10.0/24 via 192.168.0.1 dev eth0
172.16.1.0/24 via 192.168.0.1 dev eth0
```

Static routes should only be configured for other subnets. The above example is not necessary, since packets going to the 10.10.10.0/24 and 172.16.1.0/24 networks will use the default gateway anyway. Below is an example of setting static routes to a different subnet, on a machine in a 192.168.0.0/24 subnet. The example machine has an `eth0` interface in the 192.168.0.0/24 subnet, and an `eth1` interface (10.10.10.1) in the 10.10.10.0/24 subnet:

```
10.10.10.0/24 via 10.10.10.1 dev eth1
```

Specifying an exit interface is optional. It can be useful if you want to force traffic out of a specific interface. For example, in the case of a VPN, you can force traffic to a remote network to pass through a tun0 interface even when the interface is in a different sub-net to the destination network.



Duplicate default gateways

If the default gateway is already assigned from DHCP, the IP command arguments format can cause one of two errors during start-up, or when bringing up an interface from the down state using the **ifup** command: "RTNETLINK answers: File exists" or 'Error: either "to" is a duplicate, or "*X.X.X.X*" is a garbage.', where *X.X.X.X* is the gateway, or a different IP address. These errors can also occur if you have another route to another network using the default gateway. Both of these errors are safe to ignore.

Network/Netmask Directives Format

You can also use the network/netmask directives format for **route-*interface*** files. The following is a template for the network/netmask format, with instructions following afterwards:

```
ADDRESS0=X.X.X.X NETMASK0=X.X.X.X GATEWAY0=X.X.X.X
```

- **ADDRESS0=*X.X.X.X*** is the network number for the static route.
- **NETMASK0=*X.X.X.X*** is the netmask for the network number defined with **ADDRESS0=*X.X.X.X***.
- **GATEWAY0=*X.X.X.X*** is the default gateway, or an IP address that can be used to reach **ADDRESS0=*X.X.X.X***

The following is a sample **route-eth0** file using the network/netmask directives format. The default gateway is 192.168.0.1, interface `eth0`. The two static routes are for the 10.10.10.0/24 and 172.16.1.0/24 networks. However, as mentioned before, this example is not necessary as the 10.10.10.0/24 and 172.16.1.0/24 networks would use the default gateway anyway:

```
ADDRESS0=10.10.10.0
NETMASK0=255.255.255.0
GATEWAY0=192.168.0.1
ADDRESS1=172.16.1.0
NETMASK1=255.255.255.0
GATEWAY1=192.168.0.1
```

Subsequent static routes must be numbered sequentially, and must not skip any values. For example, **ADDRESS0**, **ADDRESS1**, **ADDRESS2**, and so on.

Below is an example of setting static routes to a different subnet, on a machine in the 192.168.0.0/24 subnet. The example machine has an `eth0` interface in the 192.168.0.0/24 subnet, and an `eth1` interface (10.10.10.1) in the 10.10.10.0/24 subnet:

```
ADDRESS0=10.10.10.0
NETMASK0=255.255.255.0
GATEWAY0=10.10.10.1
```

Note that if DHCP is used, it can assign these settings automatically.

7.5. Network Function Files

Fedora makes use of several files that contain important common functions used to bring interfaces up and down. Rather than forcing each interface control file to contain these functions, they are grouped together in a few files that are called upon when necessary.

The **/etc/sysconfig/network-scripts/network-functions** file contains the most commonly used IPv4 functions, which are useful to many interface control scripts. These functions include contacting running programs that have requested information about changes in the status of an interface, setting hostnames, finding a gateway device, verifying whether or not a particular device is down, and adding a default route.

As the functions required for IPv6 interfaces are different from IPv4 interfaces, a **/etc/sysconfig/network-scripts/network-functions-ipv6** file exists specifically to hold this information. The functions in this file configure and delete static IPv6 routes, create and remove tunnels, add and remove IPv6 addresses to an interface, and test for the existence of an IPv6 address on an interface.

7.6. Additional Resources

The following are resources which explain more about network interfaces.

7.6.1. Installed Documentation

/usr/share/doc/initscripts-*version*/sysconfig.txt
: A guide to available options for network configuration files, including IPv6 options not covered in this chapter.

7.6.2. Useful Websites

http://linux-ip.net/gl/ip-cref/
: This document contains a wealth of information about the ip command, which can be used to manipulate routing tables, among other things.

Part IV. Infrastructure Services

This part provides information how to configure services and daemons, configure authentication, and enable remote logins.

Services and Daemons

Maintaining security on your system is extremely important, and one approach for this task is to manage access to system services carefully. Your system may need to provide open access to particular services (for example, `httpd` if you are running a web server). However, if you do not need to provide a service, you should turn it off to minimize your exposure to possible bug exploits.

This chapter covers the configuration of the services to be run when a system is started, and provides information on how to start, stop, and restart the services on the command line using the **systemctl** utility.



Keep the system secure

When you allow access for new services, always remember that both the firewall and **SELinux** need to be configured as well. One of the most common mistakes committed when configuring a new service is neglecting to implement the necessary firewall configuration and SELinux policies to allow access for it. For more information, refer to the Fedora 17 *Security Guide*.

8.1. Configuring Services

To allow you to configure which services are started at boot time, Fedora is shipped with the **systemctl** command line tool.



Do not use the ntsysv and chkconfig utilities

Although it is still possible to use the **ntsysv** and **chkconfig** utilities to manage services that have init scripts installed in the **`/etc/rc.d/init.d/`** directory, it is advised that you use the **systemctl** utility.



Enabling the irqbalance service

To ensure optimal performance on POWER architecture, it is recommended that the `irqbalance` service is enabled. In most cases, this service is installed and configured to run during the Fedora 17 installation. To verify that `irqbalance` is running, type the following at a shell prompt:

```
systemctl status irqbalance.service
```

8.1.1. Enabling the Service

To configure a service to be automatically started at boot time, use the **`systemctl`** command in the following form:

```
systemctl enable service_name.service
```

The service will be started the next time you boot the system. For information on how to start the service immediately, refer to *Section 8.2.2, "Running the Service"*.

> Example 8.1. Enabling the httpd service
> Imagine you want to run the Apache HTTP Server on your system. Provided that you have the *httpd* package installed, you can enable the `httpd` service by typing the following at a shell prompt as `root`:
>
> ```
> ~]# systemctl enable httpd.service
> ```

8.1.2. Disabling the Service

To disable starting a service at boot time, use the **`systemctl`** command in the following form:

```
systemctl disable service_name.service
```

The next time you boot the system, the service will *not* be started. For information on how to stop the service immediately, refer to *Section 8.2.3, "Stopping the Service"*.

> Example 8.2. Disabling the telnet service
> In order to secure the system, users are advised to disable insecure connection protocols such as Telnet. You can make sure that the `telnet` service is disabled by running the following command as `root`:
>
> ```
> ~]# systemctl disable telnet.service
> ```

8.2. Running Services

The **systemctl** utility also allows you to determine the status of a particular service, as well as to start, stop, or restart a service.



Do not use the service utility

Although it is still possible to use the **service** utility to manage services that have init scripts installed in the **`/etc/rc.d/init.d/`** directory, it is advised that you use the **systemctl** utility.

8.2.1. Checking the Service Status

To determine the status of a particular service, use the **`systemctl`** command in the following form:

```
systemctl status service_name.service
```

This command provides detailed information on the service's status. However, if you merely need to verify that a service is running, you can use the **`systemctl`** command in the following form instead:

```
systemctl is-active service_name.service
```

Example 8.3. Checking the status of the httpd service

Example 8.1, "Enabling the httpd service" illustrated how to enable starting the `httpd` service at boot time. Imagine that the system has been restarted and you need to verify that the service is really running. You can do so by typing the following at a shell prompt:

```
~]$ systemctl is-active httpd.service
active
```

You can also display detailed information about the service by running the following command:

```
~]$ systemctl status httpd.service
httpd.service - LSB: start and stop Apache HTTP Server
          Loaded: loaded (/etc/rc.d/init.d/httpd)
          Active: active (running) since Mon, 23 May 2011 21:38:57 +0200; 27s ago
         Process: 2997 ExecStart=/etc/rc.d/init.d/httpd start (code=exited, status=0/
SUCCESS)
        Main PID: 3002 (httpd)
          CGroup: name=systemd:/system/httpd.service
                  ├ 3002 /usr/sbin/httpd
                  ├ 3004 /usr/sbin/httpd
                  ├ 3005 /usr/sbin/httpd
                  ├ 3006 /usr/sbin/httpd
                  ├ 3007 /usr/sbin/httpd
                  ├ 3008 /usr/sbin/httpd
                  ├ 3009 /usr/sbin/httpd
                  ├ 3010 /usr/sbin/httpd
                  └ 3011 /usr/sbin/httpd
```

To display a list of all active system services, use the following command:

```
systemctl list-units --type=service
```

This command provides a tabular output with each line consisting of the following columns:

- **UNIT** — A `systemd` unit name. In this case, a service name.
- **LOAD** — Information whether the `systemd` unit was properly loaded.
- **ACTIVE** — A high-level unit activation state.
- **SUB** — A low-level unit activation state.
- **JOB** — A pending job for the unit.
- **DESCRIPTION** — A brief description of the unit.

Example 8.4. Listing all active services

You can list all active services by using the following command:

```
~]$ systemctl list-units --type=service
UNIT                     LOAD   ACTIVE SUB     JOB DESCRIPTION
abrt-ccpp.service        loaded active exited      LSB: Installs coredump handler which
 saves segfault data
abrt-oops.service        loaded active running     LSB: Watches system log for oops
 messages, creates ABRT dump directories for each oops
```

```
abrtd.service              loaded active running     ABRT Automated Bug Reporting Tool
accounts-daemon.service    loaded active running     Accounts Service
atd.service                loaded active running     Job spooling tools
[output truncated]
```

In the example above, the `abrtd` service is loaded, active, and running, and it does not have any pending jobs.

8.2.2. Running the Service

To run a service, use the **`systemctl`** command in the following form:

```
systemctl start service_name.service
```

This will start the service in the current session. To configure the service to be started at boot time, refer to *Section 8.1.1, "Enabling the Service"*.

Example 8.5. Running the httpd service

Example 8.1, "Enabling the httpd service" illustrated how to run the `httpd` service at boot time. You can start the service immediately by typing the following at a shell prompt as `root`:

```
~]# systemctl start httpd.service
```

8.2.3. Stopping the Service

To stop a service, use the **`systemctl`** command in the following form:

```
systemctl stop service_name.service
```

This will stop the service in the current session. To disable starting the service at boot time, refer to *Section 8.1.1, "Enabling the Service"*.

Example 8.6. Stopping the telnet service

Example 8.2, "Disabling the telnet service" illustrated how to disable starting the `telnet` service at boot time. You can stop the service immediately by running the following command as `root`:

```
~]# systemctl stop telnet.service
```

8.2.4. Restarting the Service

To restart a service, use the **`systemctl`** command in the following form:

```
systemctl restart service_name.service
```

Example 8.7. Restarting the sshd service

For any changes in the **`/etc/ssh/sshd_config`** configuration file to take effect, it is required that you restart the `sshd` service. You can do so by typing the following at a shell prompt as `root`:

```
~]# systemctl restart sshd.service
```

8.3. Additional Resources

8.3.1. Installed Documentation

- **`systemctl`**(1) — The manual page for the **systemctl** utility.

8.3.2. Related Books

Fedora 17 Security Guide

A guide to securing Fedora. It contains valuable information on how to set up the firewall, as well as the configuration of **SELinux**.

Configuring Authentication

9.1. The Authentication Configuration Tool

When a user logs in to a Fedora system, the username and password combination must be verified, or *authenticated*, as a valid and active user. Sometimes the information to verify the user is located on the local system, and other times the system defers the authentication to a user database on a remote system.

The **Authentication Configuration Tool** provides a graphical interface for configuring user information retrieval from *Lightweight Directory Access Protocol* (LDAP), *Network Information Service* (NIS), and *Winbind* user account databases. This tool also allows you to configure Kerberos to be used as the authentication protocol when using LDAP or NIS.



Using a high or medium security level

If you configured a medium or high security level during installation (or with the **Security Level Configuration Tool**), then the firewall will prevent NIS authentication. For more information about firewalls, refer to the *"Firewalls"* section of the Fedora 17 *Security Guide*.

To start the graphical version of the **Authentication Configuration** tool from the desktop, select **Applications**□□□ **Other**□□□ **Authentication** form the **Activities** menu or type the command **`system-config-authentication`** at a shell prompt (for example, in an **XTerm** or a **GNOME** terminal).



Your changes are immediately applied

After exiting the authentication program, any changes you made take effect immediately.

9.1.1. Identity & Authentication

The **Identity & Authentication** tab allows you to configure how users should be authenticated, and has several options for each method of authentication. To select which user account database should be used, select an option from the drop-down list.

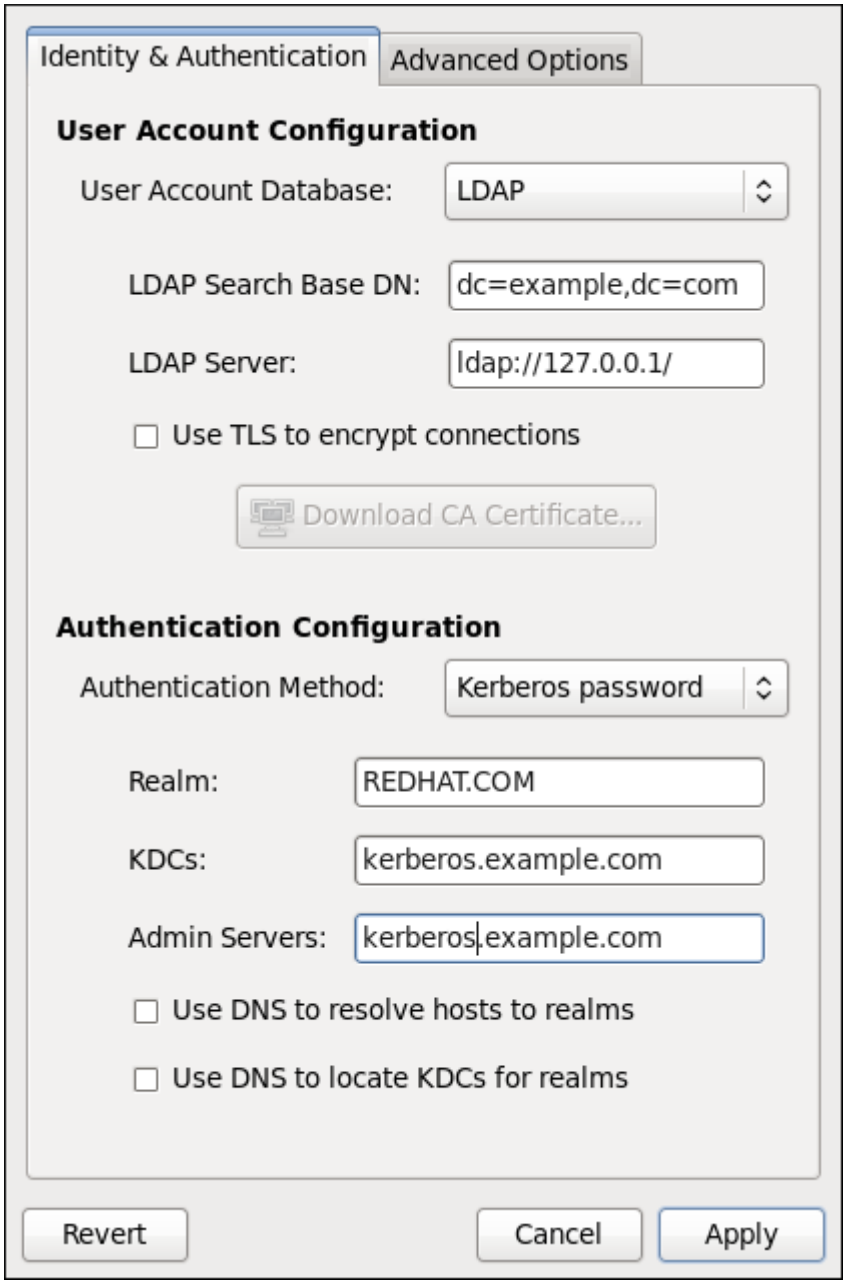


Figure 9.1. Identity & Authentication; changing the option in the User Account Database drop-down list changes the contents of the tab

The following list explains what each option configures:

LDAP

The **LDAP** option instructs the system to retrieve user information via LDAP. It contains the following specifications:

- **LDAP Search Base DN** — Specifies that user information should be retrieved using the listed Distinguished Name (DN).
- **LDAP Server** — Specifies the address of the LDAP server.
- **Use TLS to encrypt connections** — When enabled, `Transport Layer Security` (TLC) will be used to encrypt passwords sent to the LDAP server. The **Download CA Certificate** option allows

you to specify a URL from which to download a valid *Certificate Authority certificate* (CA). A valid CA certificate must be in the *Privacy Enhanced Mail* (PEM) format.



Using ldaps:// in the LDAP Server field

The **Use TLS to encrypt connections** option must not be ticked if an `ldaps://` server address is specified in the **LDAP Server** field.

For more information about CA Certificates, refer to *Section 13.1.8.1, "An Overview of Certificates and Security"*.

The **`openldap-clients`** package must be installed for this option to work.

For more information about LDAP, refer to *Section 15.1, "OpenLDAP"*.

LDAP provides the following methods of authentication:

- **Kerberos password** — This option enables Kerberos authentication. It contains the following specifications:
  - **Realm** — Configures the realm for the Kerberos server. The realm is the network that uses Kerberos, composed of one or more KDCs and a potentially large number of clients.
  - **KDCs** — Defines the Key Distribution Centers (KDC), which are servers that issue Kerberos tickets.
  - **Admin Servers** — Specifies the administration server(s) running **`kadmind`**.

  The **Kerberos Settings** dialog also allows you to use DNS to resolve hosts to realms and locate KDCs for realms.

  The **`krb5-libs`** and **`krb5-workstation`** packages must be installed for this option to work. For more information about Kerberos, refer to section *Using Kerberos* of the Fedora 17 *Managing Single Sign-On and Smart Cards* guide.
- **LDAP password** — This option instructs standard PAM-enabled applications to use LDAP authentication with options specified in the User Account Configuration of LDAP. When using this option, you must provide an `ldaps://` server address or use TLS for LDAP authentication.



Setting up the SSSD service

The SSSD service is used as a client for LDAP and Kerberos servers. Thus, offline login is enabled and supported by default. No user interaction is needed to set up the SSSD service with the **Authentication Configuration Tool**. For more information about the SSSD service, refer to *Section 9.2, "The System Security Services Daemon (SSSD)"*

NIS

The **NIS** option configures the system to connect to a NIS server (as an NIS client) for user and password authentication. To configure this option, specify the NIS domain and NIS server. If the NIS server is not specified, the daemon attempts to find it via broadcast.

The *ypbind* package must be installed for this option to work. If the NIS user account database is used, the `portmap` and `ypbind` services are started and are also enabled to start at boot time.

For more information about NIS, refer to section *"Securing NIS"* of the Fedora 17 *Security Guide*.

NIS provides the following methods of authentication:

- **Kerberos password** — This option enables Kerberos authentication. For more information about configuration of the Kerberos authentication method, refer to the previous section on LDAP.
- **NIS password** — This option enables NIS authentication. NIS can provide authentication information to outside processes to authenticate users.

Winbind

The **Winbind** option configures the system to connect to a Windows Active Directory or a Windows domain controller. User information from the specified directory or domain controller can then be accessed, and server authentication options can be configured. It contains the following specifications:

- **Winbind Domain** — Specifies the Windows Active Directory or domain controller to connect to.
- **Security Model** — Allows you to select a security model, which configures the Samba client mode of operation. The drop-down list allows you to select any of the following:
  - **ads** — This mode instructs Samba to act as a domain member in an Active Directory Server (ADS) realm. To operate in this mode, the **`krb5-server`** package must be installed, and Kerberos must be configured properly.
  - **domain** — In this mode, Samba will attempt to validate the username/password by authenticating it through a Windows NT Primary or Backup Domain Controller, similar to how a Windows NT Server would.
  - **server** — In this mode, Samba will attempt to validate the username/password by authenticating it through another SMB server (for example, a Windows NT Server). If the attempt fails, the **user** mode will take effect instead.
  - **user** — This is the default mode. With this level of security, a client must first log in with a valid username and password. Encrypted passwords can also be used in this security mode.
- **Winbind ADS Realm** — When the **ads** Security Model is selected, this allows you to specify the ADS Realm the Samba server should act as a domain member of.
- **Winbind Domain Controllers** — Use this option to specify which domain controller **`winbind`** should use. For more information about domain controllers, please refer to *Section 16.1.6.3, "Domain Controller"*.
- **Template Shell** — When filling out the user information for a Windows NT user, the **`winbindd`** daemon uses the value chosen here to specify the login shell for that user.
- **Allow offline login** — By checking this option, you allow authentication information to be stored in a local cache (provided by SSSD). This information is then used when a user attempts to authenticate while offline.

For more information about the **winbindd** service, refer to *Section 16.1.2, "Samba Daemons and Related Services"*.

Winbind provides only one method of authentication, **Winbind password**. This method of authentication uses the options specified in the User Account Configuration of Winbind to connect to a Windows Active Directory or a Windows domain controller.

9.1.2. Advanced Options

This tab allows you to configure advanced options, as listed below.

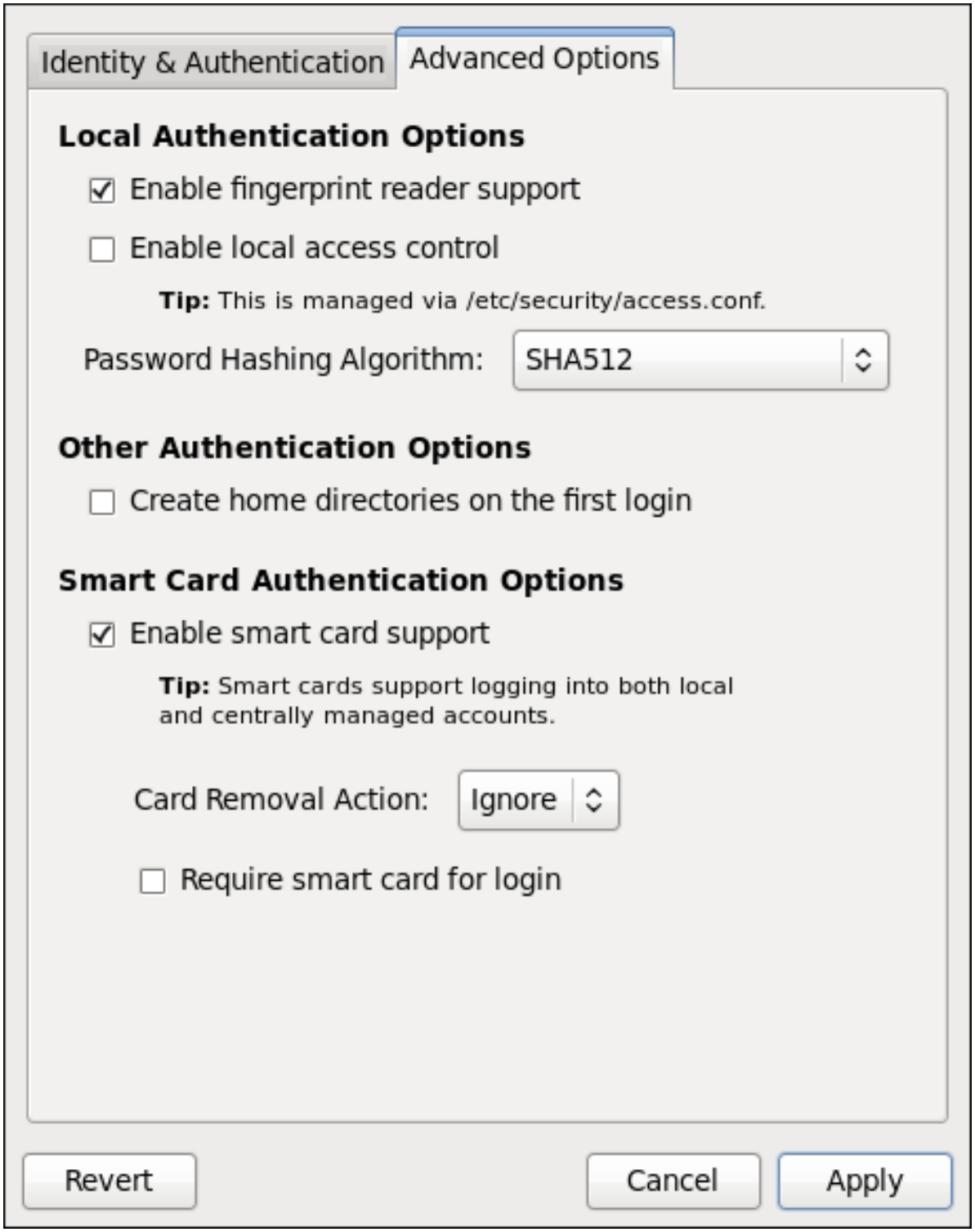


Figure 9.2. Advanced Options

Local Authentication Options

- **Enable fingerprint reader support** — By checking this option, you enable fingerprint authentication to log in by scanning your finger with the fingerprint reader.
- **Enable local access control** — When enabled, **`/etc/security/access.conf`** is consulted for authorization of a user.

- **Password Hashing Algorithm** — This option lets you specify which hashing or cryptographic algorithm should be used to encrypt locally stored passwords.

Other Authentication Options

Create home directories on the first login — When enabled, the user's home directory is automatically created when they log in if it does not already exist.

Smart Card Authentication Options

Enable smart card support — This option enables smart card authentication. Smart card authentication allows you to log in using a certificate and a key associated with a smart card.

When the **Enable smart card support** option is checked, the following options can be specified:

- **Card Removal Action** — This option defines what action the system performs when the card is removed from the card reader during an active session. Two alternatives are available:
  - **Ignore** — The card removal is ignored and the system continues to function as normal.
  - **Lock** — The current session is immediately locked.
- **Require smart card login** — Requires the user to login and authenticate with a smart card. It essentially disables any other type of password authentication. This option should not be selected until after you have successfully logged in using a smart card.

The *pam_pkcs11* and the *coolkey* packages must be installed for this option to work. For more information about smart cards, refer to the Red Hat Enterprise Linux 6 *Managing Single Sign-On and Smart Cards Guide*[1].



Click Revert to restore the previous configuration

You can restore all of the options specified in the **Authentication Configuration Tool** to the previous configuration setup by clicking **Revert**.

9.1.3. Command Line Version

The **Authentication Configuration** tool also supports a command line interface. The command line version can be used in a configuration script or a kickstart script. The authentication options are summarized in *Table 9.1, "Command line options"*.



Getting the list of supported authentication options

These options can also be found in the **`authconfig`** man page or by typing **`authconfig --help`** at the shell prompt.

[1] http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Managing_Smart_Cards/enabling-smart-card-login.html

Table 9.1. Command line options

Option	Description
--enableshadow, --useshadow	Enable shadow passwords
--disableshadow	Disable shadow passwords
--passalgo=*descrypt*|*bigcrypt*|*md5*|*sha256*|*sha512*	Hash/crypt algorithm to be used
--enablenis	Enable NIS for user account configuration
--disablenis	Disable NIS for user account configuration
--nisdomain=*domain*	Specify an NIS domain
--nisserver=*server*	Specify an NIS server
--enableldap	Enable LDAP for user account configuration
--disableldap	Disable LDAP for user account configuration
--enableldaptls	Enable use of TLS with LDAP
--disableldaptls	Disable use of TLS with LDAP
--enablerfc2307bis	Enable use of RFC-2307bis schema for LDAP user information lookups
--disablerfc2307bis	Disable use of RFC-2307bis schema for LDAP user information lookups
--enableldapauth	Enable LDAP for authentication
--disableldapauth	Disable LDAP for authentication
--ldapserver=*server*	Specify an LDAP server
--ldapbasedn=*dn*	Specify an LDAP base DN (Distinguished Name)
--ldaploadcacert=*URL*	Load a CA certificate from the specified URL
--enablekrb5	Enable Kerberos for authentication
--disablekrb5	Disable Kerberos for authentication
--krb5kdc=*server*	Specify Kerberos KDC server
--krb5adminserver=*server*	Specify Kerberos administration server
--krb5realm=*realm*	Specify Kerberos realm
--enablekrb5kdcdns	Enable use of DNS to find Kerberos KDCs
--disablekrb5kdcdns	Disable use of DNS to find Kerberos KDCs
--enablekrb5realmdns	Enable use of DNS to find Kerberos realms
--disablekrb5realmdns	Disable use of DNS to find Kerberos realms

Option	Description
--enablewinbind	Enable winbind for user account configuration
--disablewinbind	Disable winbind for user account configuration
--enablewinbindauth	Enable winbindauth for authentication
--disablewinbindauth	Disable winbindauth for authentication
--winbindseparator=	Character used to separate the domain and user part of winbind usernames if **winbindusedefaultdomain** is not enabled
--winbindtemplatehomedir=*/home/%D/%U*	Directory that winbind users have as their home
--winbindtemplateprimarygroup=*nobody*	Group that winbind users have as their primary group
--winbindtemplateshell=*/bin/false*	Shell that winbind users have as their default login shell
--enablewinbindusedefaultdomain	Configures winbind to assume that users with no domain in their usernames are domain users
--disablewinbindusedefaultdomain	Configures winbind to assume that users with no domain in their usernames are not domain users
--winbindjoin=*Administrator*	Joins the winbind domain or ADS realm as the specified administrator
--enablewinbindoffline	Configures winbind to allow offline login
--disablewinbindoffline	Configures winbind to prevent offline login
--smbsecurity=*user*|*server*|*domain*|*ads*	Security mode to use for the Samba and Winbind services
--smbrealm=*realm*	Default realm for Samba and Winbind services when **security** is set to **ads**
--enablewins	Enable Wins for hostname resolution
--disablewins	Disable Wins for hostname resolution
--enablesssd	Enable SSSD for user information
--disablesssd	Disable SSSD for user information
--enablecache	Enable **nscd**
--disablecache	Disable **nscd**
--enablelocauthorize	Local authorization is sufficient for local users
--disablelocauthorize	Local users are also authorized through a remote service

Option	Description
--enablesysnetauth	Authenticate system accounts with network services
--disablesysnetauth	Authenticate system accounts with local files only
--enablepamaccess	Check **/etc/security/access.conf** during account authorization
--disablepamaccess	Do not check **/etc/security/access.conf** during account authorization
--enablemkhomedir	Create a home directory for a user on the first login
--disablemkhomedir	Do not create a home directory for a user on the first login
--enablesmartcard	Enable authentication with a smart card
--disablesmartcard	Disable authentication with a smart card
--enablerequiresmartcard	Require smart card for authentication
--disablerequiresmartcard	Do not require smart card for authentication
--smartcardmodule=*module*	Default smart card module to use
--smartcardaction=*0=Lock*|*1=Ignore*	Action to be taken when smart card removal is detected
--enablefingerprint	Enable fingerprint authentication
--disablefingerprint	Disable fingerprint authentication
--nostart	Do not start or stop the **portmap**, **ypbind**, or **nscd** services even if they are configured
--test	Do not update the configuration files, only print the new settings
--update, --kickstart	Opposite of **--test**, update configuration files with changed settings
--updateall	Update all configuration files
--probe	Probe and display network defaults
--savebackup=*name*	Save a backup of all configuration files
--restorebackup=*name*	Restore a backup of all configuration files
--restorelastbackup	Restore the backup of configuration files saved before the previous configuration change

9.2. The System Security Services Daemon (SSSD)

This section provides an introduction to the *System Security Services Daemon (SSSD)*, the main features that it provides, and discusses the requirements and any limitations of a typical SSSD deployment.

This section also describes how to configure SSSD, and how to use the features that it provides. It provides information on the types of services that it supports and how to configure them, and introduces and describes the most important configuration options. Sample configuration files are also provided to help you optimize your deployment.

9.2.1. What is SSSD?

The System Security Services Daemon (SSSD) is a service which provides access to different identity and authentication providers. You can configure SSSD to use a native LDAP domain (that is, an LDAP identity provider with LDAP authentication), or an LDAP identity provider with Kerberos authentication. It provides an NSS and PAM interface to the system, and a pluggable back-end system to connect to multiple different account sources.

SSSD is also extensible; you can configure it to use new identity sources and authentication mechanisms should they arise. In addition, SSSD is fully IPv6-compatible, provided that it is built against *c-ares 1.7.1* or later and *krb5-libs 1.8.1* or later.

9.2.2. SSSD Features

9.2.2.1. Offline Authentication

One of the primary benefits of SSSD is offline authentication. This solves the case of users having a separate corporate account and a local machine account because of the common requirement to implement a Virtual Private Network (VPN).

SSSD can cache remote identities and authentication credentials. This means that you can still authenticate with these remote identities even when a machine is offline. In an SSSD system, you only need to manage one account.

9.2.2.2. Server Load Reduction

The use of SSSD also helps to reduce the load on identification servers. For example, using *nss_ldap*, every client application that needs to request user information opens its own connection to the LDAP server. Managing these multiple connections can lead to a heavy load on the LDAP server. In an SSSD system, only the SSSD Data Provider process actually communicates with the LDAP server, reducing the load to one connection per client system.

9.2.2.3. Support for Multiple Domains

You can use SSSD to specify multiple domains of the same type. Compare this to an **`nsswitch.conf`** file configuration, with which you can only request user information from a single server of any particular type (LDAP, NIS, etc.). With SSSD, you can create multiple domains of the same, or of different types of identity provider.

Beginning with version 0.6.0, SSSD maintains a separate database file for each domain. This means that each domain has its own cache, and in the event that problems occur and maintenance is necessary, it is very easy to purge the cache for a single domain, by stopping `sssd` and deleting the corresponding cache file. These cache files are stored in the **`/var/lib/sss/db/`** directory.

All cache files are named according to the domain that they represent, for example **cache_*DOMAINNAME*.ldb**.

Considerations Associated with Deleting Cache Files

Deleting a domain's cache file can have some unexpected side effects. You should be aware of the following before you proceed:

- Deleting the cache file also deletes all user data (both identification and cached credentials). Consequently, you should not proceed unless you are online and can authenticate with your username against the domain's servers, because offline authentication will fail.
- If you are online and change your configuration to reference a different identity provider, SSSD will recognize users from both providers until the cached entries from the original provider time out.

  To avoid this situation, you can either purge the cache or use a different domain name for the new provider (this is the recommended practice). Changing the domain name means that when you restart SSSD it will create a new cache file (with the new name) and the old file will be ignored.

9.2.2.4. Support for LDAP Referrals

SSSD supports two types of LDAP referrals: object-level referrals and subtree referrals. These referral types and the extent of SSSD support is outlined below.

9.2.2.4.1. Object-level Referrals

SSSD provides full support for object-level referrals within the same LDAP server, correctly handling any differences in the distinguished name (DN) that might exist as part of the LDAP server referral configuration.

SSSD provides partial support for object-level referrals between different LDAP servers, and requires that the full DN of an LDAP request be identical on each server. SSSD does not support referrals to different DN paths on other servers.

9.2.2.4.2. Subtree Referrals

SSSD provides a similar level of support for subtree referrals as it does for object-level referrals. That is, it supports referrals to a changed DN on the local system or to an identical DN on a remote system. The difference with subtree referrals, however, is the ability to set up identical subtrees on each LDAP server and to then configure referrals between these subtrees.

9.2.2.4.3. Enabling LDAP Referrals

To take advantage of the SSSD LDAP referral functionality, you need to set the **ldap_referrals** option to **TRUE** in the LDAP domain configuration section of the **/etc/sssd/sssd.conf** file. This will enable anonymous access to the second LDAP server.



Make sure SSSD is compiled with OpenLDAP version 2.4.13 or later

SSSD only supports LDAP referrals when it is compiled with OpenLDAP version 2.4.13 or later.

9.2.2.5. Differentiating Like-named Users

SSSD supports the differentiation of like-named users in different domains. For example, you can differentiate the user `kate` in the `ldap.example.com` domain from the user `kate` in the `ldap.myhome.com` domain. You can use SSSD to make requests using fully-qualified usernames. If you request information for `kate`, you will receive the information from whichever domain is listed first in the look-up order. If you request information for `kate@ldap.myhome.com`, however, you will receive the correct user information.

SSSD also provides a **`filter_users`** option, which you can use to exclude certain users from being fetched from the database. Refer to the *sssd.conf(5)* manual page for full details about this option.

9.2.2.6. Integration with IPA

Beyond the offline authentication, multiple domain management and other features already described, SSSD is also designed to integrate with and enhance the functionality of IPA clients. In an environment with the latest version of IPA installed, SSSD provides additional functionality, including support for dynamic DNS updates, host-based access control, and password migration from an LDAP-only environment into the LDAP/Kerberos 5 environment employed by IPA.

9.2.2.6.1. Support for Dynamic DNS Updates

Because the IP address of IPA clients can change, SSSD provides the ability to dynamically update the client's DNS entry on the IPA server. Using a combination of Kerberos and GSS-TSIG (Generic Security Service Algorithm for Secret Key Transaction), IPA can determine the identity of the host machine, authenticate it, and allow that machine to edit its own DNS record. These changes are then stored in the LDAP back end.



Each IPA client can only edit its own DNS record

Using this authentication system means that each IPA client can only edit its own DNS record; it cannot edit the DNS record of any other client.

Setting up Dynamic DNS Updates

The SSSD configuration file provides two options used for setting up dynamic DNS updates: **`ipa_dyndns_update`**, used to enable dynamic DNS updates; and **`ipa_dyndns_iface`**, which specifies the interface whose IP address should be used for dynamic DNS updates.

Refer to the *sssd-ipa* manual page for more information about these options, and how to configure dynamic DNS updates.



Support for dynamic DNS updates

Support for dynamic DNS updates is only available on IPA version 2 or later, and with DNS correctly configured.

9.2.3. Setting Up SSSD

This section describes how to install SSSD, how to run the service, and how to configure it for each type of supported information provider.

9.2.3.1. Installing SSSD

Run the following command to install SSSD and any dependencies, including the SSSD client:

```
# yum install sssd
```

SSSD requires very few dependencies and should install very quickly, depending on the speed of your network connection.

9.2.3.1.1. Upgrading from a Previous Version

Upgrading Using RPM Packages

If you are upgrading using RPM packages, the script will run automatically when you upgrade to the new version. This will upgrade the **/etc/sssd/sssd.conf** file to the new format, and copy the existing version to **/etc/sssd/sssd.conf.bak**.

Upgrading Manually

It may be necessary to run the upgrade script manually, either because you built SSSD from source files, or because you are using a platform that does not support the use of RPM packages. The synopsis for the script is as follows:

upgrade_config.py [-f INFILE] [-o OUTFILE] [-verbose] [--no-backup]

- *-f INFILE* — the configuration file to upgrade. If not specified, this defaults to **/etc/sssd/sssd.conf**
- *-o OUTFILE* — the name of the upgraded configuration file. If not specified, this defaults to **/etc/sssd/sssd.conf**
- *-verbose* — produce more verbose output during the upgrade process
- *--no-backup* — do not produce a back-up file. If not specified, this defaults to ***INFILE*.bak**

9.2.3.1.2. Starting and Stopping SSSD

Starting SSSD for the first time

Before you start SSSD for the first time, you need to configure at least one domain. Refer to *Section 9.2.5, "Configuring Domains"* for information on how to configure an SSSD domain.

You can use either the **service** command or the **/etc/init.d/sssd** script to control SSSD. For example, run the following command to start `sssd`:

```
# systemctl start sssd.service
```

By default, SSSD is configured not to start automatically. There are two ways to change this behavior; if you use the Authentication Configuration tool to configure SSSD, it will reconfigure the default behavior so that SSSD starts when the machine boots. Alternatively, you can use the **systemctl** command, as follows:

```
# systemctl enable sssd.service
```

9.2.3.2. Configuring SSSD

The global configuration of SSSD is stored in the **/etc/sssd/sssd.conf** file. This file consists of various sections, each of which contains a number of key/value pairs. Some keys accept multiple values; use commas to separate multiple values for such keys. This configuration file uses data types of string (no quotes required), integer and Boolean (with values of **TRUE** or **FALSE**). Comments are indicated by either a hash sign (#) or a semicolon (;) in the first column. The following example illustrates some of this syntax:

```
[section]
# Keys with single values
key1 = value
key2 = val2

# Keys with multiple values
key10 = val10,val11
```



Specifying a different configuration file

You can use the *-c* (or *--config*) parameter on the command line to specify a different configuration file for SSSD.

The format of the configuration file is described in *Section 9.2.9, "SSSD Configuration File Format"*

Refer to the *sssd.conf(5)* manual page for more information on global SSSD configuration options.

9.2.3.2.1. Configuring NSS

SSSD provides a new NSS module, `sssd_nss`, so that you can configure your system to use SSSD to retrieve user information. Edit the **/etc/nsswitch.conf** file for your system to use the `sss` name database. For example:

```
passwd: files sss
group: files sss
```

9.2.3.2.2. Configuring PAM



Be careful when changing your PAM configuration

Use extreme care when changing your PAM configuration. A mistake in the PAM configuration file can lock you out of the system completely. Always back up your configuration files before performing any changes, and keep a session open so that you can revert any changes you make should the need arise.

To enable your system to use SSSD for PAM, you need to edit the default PAM configuration file. On Fedora—based systems, this is the **/etc/pam.d/system-auth** file. Edit this file to reflect the following example, and then restart `sssd`:

```
#%PAM-1.0
# This file is auto-generated.
# User changes will be destroyed the next time authconfig is run.
auth        required      pam_env.so
auth        sufficient    pam_unix.so nullok try_first_pass
auth        requisite     pam_succeed_if.so uid >= 500 quiet
auth        sufficient    pam_sss.so use_first_pass
auth        required      pam_deny.so

account     required      pam_unix.so broken_shadow
account     sufficient    pam_localuser.so
account     sufficient    pam_succeed_if.so uid < 500 quiet
account [default=bad success=ok user_unknown=ignore] pam_sss.so
account     required      pam_permit.so

password    requisite     pam_cracklib.so try_first_pass retry=3
password    sufficient    pam_unix.so sha512 shadow nullok try_first_pass use_authtok
password    sufficient    pam_sss.so use_authtok
password    required      pam_deny.so

session     required      pam_mkhomedir.so umask=0022 skel=/etc/skel/
session     optional      pam_keyinit.so revoke
session     required      pam_limits.so
session     [success=1 default=ignore] pam_succeed_if.so service in crond quiet use_uid
session     sufficient    pam_sss.so
session     required      pam_unix.so
```

9.2.3.2.2.1. Using Custom Home Directories with SSSD

If your LDAP users have home directories that are not in **/home**, and if your system is configured to create home directories the first time your users log in, then these directories will be created with the wrong permissions. For example, instead of a typical home directory such as **/home/<username>**, your users might have home directories that include their locale, such as **/home/<locale>/<username>**. If this is true for your system, the following steps need to be taken (preemptively):

1. Apply the correct SELinux context and permissions from the **/home** directory to the home directory that you use on your system. In the example above, the following command would achieve this result (replace the directory names with those that apply to your system):

   ```
   # semanage fcontext -a -e /home /home/locale
   ```

2. Ensure the *oddjob-mkhomedir* package is installed on your system and then re-run the Authentication Configuration tool.

   This package provides the `pam_oddjob_mkhomedir.so` library, which the Authentication Configuration tool will then use to create your custom home directories. You need to use this library to create your home directories, and not the default `pam_mkhomedir.so` library, because the latter cannot create SELinux labels.

   The pam_oddjob_mkhomedir and pam_mkhomedir libraries

   The Authentication Configuration tool will automatically use the `pam_oddjob_mkhomedir.so` library if it is available. Otherwise, it will default to using `pam_mkhomedir.so`.

If the preceding steps were not performed before the custom home directories were created, you can use the following commands to correct the permissions and SELinux contexts (again, replace the directory names with those that apply to your system):

```
# semanage fcontext -a -e /home /home/locale
# restorecon -R -v /home/locale
```

9.2.3.2.2. Using "include" Statements in PAM Configurations

Recent PAM implementations allow you to use **include** statements in PAM configurations. For example:

```
...
session     include      system-auth
session     optional     pam_console.so
...
```

In the preceding example, if a *sufficient* condition from **system-auth** returns PAM_SUCCESS, **pam_console.so** will not be executed.

9.2.3.2.3. Configuring Access Control

SSSD provides a rudimentary access control mechanism, offering two solutions based on the value of the **access_provider** option in the **[domain/<*NAME*>]** section in the **/etc/sssd/sssd.conf** file.

9.2.3.2.3.1. The Simple Access Provider

The first of these solutions is known as the *Simple Access Provider*, and is based on the implementation of access or deny lists of usernames. To enable the Simple Access Provider, you need to set the **access_provider** option to **simple**, and then add usernames as a comma-separated list to either the **simple_allow_users** or **simple_deny_users** options.

Using the Simple Access Provider

By using the Simple Access Provider, you can continue to support a number of network logins to maintain common network accounts on company or department laptops, but you might want to restrict the use of a particular laptop to one or two users. This means that even if a different user authenticated successfully against the same authentication provider, the Simple Access Provider would prevent that user from gaining access.

The following example demonstrates the use of the Simple Access Provider to grant access to two users. This example assumes that SSSD is correctly configured and `example.com` is one of the domains specified in the **[sssd]** section, and only shows the Simple Access Provider-specific options.

```
[domain/example.com]
access_provider = simple
simple_allow_users = user1, user2
```



Using the Local ID provider

The Local ID provider does not support **simple** as an access provider.

Access Control Rules

The Simple Access Provider adheres to the following three rules to determine which users should or should not be granted access:

- If both lists are empty, access is granted.
- If **simple_allow_users** is set, only users from this list are allowed access. This setting supersedes the **simple_deny_users** list (which would be redundant).
- If the **simple_allow_users** list is empty, users are allowed access unless they appear in the **simple_deny_users** list.



Do not define both simple_allow_users and simple_deny_users

Defining both **simple_allow_users** and **simple_deny_users** is a configuration error. If this occurs, SSSD will output an error to the **/var/log/sssd/sssd_default.log** log file when loading the back end, but continue to start normally. Future versions of SSSD will output an error and fail to start.

9.2.3.2.3.2. The LDAP Access Provider

The second access control solution uses the LDAP server itself as the access provider (**access_provider=ldap**) and the associated filter option (**ldap_access_filter**) to specify which users are granted access to the specified host. Note that these two options are codependent; if you use LDAP as your access provider then you must specify a value for the **ldap_access_filter** option, otherwise all users will be denied access. If you are not using LDAP as your access provider, then the **ldap_access_filter** option has no effect.

Using the LDAP Access Provider

The following example demonstrates the use of the LDAP Access Provider to grant access to members of the "allowedusers" group in LDAP. This example assumes that SSSD is correctly configured and `example.com` is one of the domains specified in the **[sssd]** section, and only shows the LDAP Access Provider-specific options.

```
[domain/example.com]
access_provider = ldap
ldap_access_filter = memberOf=cn=allowedusers,ou=Groups,dc=example,dc=com
```



Using offline caching

Offline caching for this feature is limited to determining whether or not the user's last online login attempt was successful. If they were granted access during their last login, they will continue to be granted access while offline, and vice-versa.

Refer to the *sssd-ldap* manual page for more information about using the LDAP Access Provider.

9.2.3.2.4. Configuring Failover

The failover feature allows back ends to automatically switch to a different server if the primary server fails. These servers are entered as a case-insensitive, comma-separated list in the **[domain/<*NAME*>]** sections of the **/etc/sssd/sssd.conf** file, and listed in order of preference. This list can contain any number of servers.

For example, if you have configured a native LDAP domain, you could specify the following as your *ldap_uri* values:

```
ldap_uri = ldap://ldap0.mydomain.org, ldap://ldap1.mydomain.org, ldap://ldap2.mydomain.org
```

In this configuration, `ldap://ldap0.mydomain.org` functions as the primary server. If this server fails, the SSSD failover mechanism first attempts to connect to `ldap1.mydomain.org`, and if that server is unavailable, it then attempts to connect to `ldap2.mydomain.org`.

If the parameter that specifies which server to connect to for the specific domain (for example, *ldap_uri*, *krb5_server*, ...) is not specified, the back end defaults to using *Use service discovery*. Refer to *Section 9.2.3.2.4.1, "Using SRV Records with Failover"* for more information on service discovery.



Do not use multiple ldap_uri parameters

Do not use multiple *ldap_uri* parameters to specify your failover servers. The failover servers must be entered as a comma-separated list of values for a single *ldap_uri* parameter. If you enter multiple *ldap_uri* parameters, SSSD only recognizes the last entry.

Future versions of SSSD will throw an error upon receiving additional *ldap_uri* entries.

9.2.3.2.4.1. Using SRV Records with Failover

SSSD also supports the use of SRV records in its failover configuration. This means that you can specify a server that is later resolved into a list of specific servers using SRV requests. The *priority* and *weight* attributes of SRV records provide further opportunity for specifying which servers should be contacted first in the event that the primary server fails.

For every service with which you want to use service discovery, you need to add a special DNS record to your DNS server using the following form:

```
_service._protocol._domain TTL priority weight port hostname
```

A typical configuration would contain multiple such records, each with a different priority (for failover) and different weights (for load balancing).

The client then makes an SRV DNS query to retrieve a list of host names, their priorities, and weights. These queries are of the form *_service._protocol._domain*, for example, **_ldap._tcp._redhat.com**. The client then sorts this list according to the priorities and weights, and connects to the first server in this sorted list.

For more information on SRV records, refer to *RFC 2782*[2].

9.2.3.2.4.2. How the Failover Mechanism Works

The failover mechanism distinguishes between machines and services. The back end first tries to resolve the hostname of a given machine; if this resolution attempt fails, the machine is considered offline. No further attempts are made to connect to this machine for any other service. If the resolution attempt succeeds, the back end tries to connect to a service on this machine. If the service connection attempt fails, then only this particular service is considered offline and the back end automatically switches over to the next service. The machine is still considered online and might still be tried for another service.

The failover mechanism does not handle DNS A records with multiple IP addresses; instead it only uses the first address. DNS round-robin cannot be used for failover. Further, providing multiple A records does not provide failover. Only the first A record is used, and if a lookup attempt on the first record fails then the system attempts no further lookups. To find multiple servers with a single request, and thus implementing failover, SSSD relies on SRV resource records, as explained in *Section 9.2.3.2.4.1, "Using SRV Records with Failover"*.

Further connection attempts are made to machines or services marked as offline after a specified period of time; this is currently hard coded to 30 seconds. If there are no more machines to try, the back end as a whole switches to offline mode, and then attempts to reconnect every 30 seconds.

9.2.4. Configuring Services

Individual pieces of SSSD functionality are provided by special SSSD services that are started and stopped together with SSSD. The services provided by SSSD have their own configuration sections. The **[sssd]** section also lists the services that are active and should be started when `sssd` starts within the **services** directive.

SSSD currently provides several services:

- `NSS` — An NSS provider service that answers NSS requests from the `sssd_nss` module.
- `PAM` — A PAM provider service that manages a PAM conversation through the `sssd_pam` PAM module.
- `monitor` — A special service that monitors all other SSSD services, and starts or restarts them as needed. Its options are specified in the **[sssd]** section of the **/etc/sssd/sssd.conf** configuration file.

9.2.4.1. Configuration Options

The following sections cover the most important SSSD configuration options. Refer to the *sssd.conf(5)* manual page that ships with SSSD for information on all the available configuration options.

[2] http://tools.ietf.org/html/rfc2782

9.2.4.1.1. General Configuration Options

- **`debug_level (integer)`**

  Sets the debug level for a particular service. This is a per-service setting (that is, it can appear in any of the **`[service/<NAME>]`** sections in the SSSD configuration file).

- **`reconnection_retries (integer)`**

  In the event of a data provider crash or restart, this specifies the number of times that a service should attempt to reconnect.



DNS lookup of IPv6 addresses

If a `DNS` lookup fails to return an `IPv4` address for a hostname, SSSD attempts to look up an `IPv6` address before returning a failure. Note that this only ensures that the async resolver identifies the correct address; there is currently a bug in the LDAP code that prevents SSSD from connecting to an LDAP server over IPv6. This is being investigated separately.

9.2.4.1.2. NSS Configuration Options

Use the following options to configure the `Name Service Switch (NSS)` service. Refer to the *sssd.conf(5)* manual page for full details about each option.

- **`enum_cache_timeout (integer)`**

  Specifies for how long (in seconds) *sssd_nss* should cache enumerations (requests for information about all users).

- **`entry_cache_nowait_percentage (integer)`**

  Specifies for how long *sssd_nss* should return cached entries before initiating an out-of-band cache refresh (**`0`** disables this feature).

  You can configure the entry cache to automatically update entries in the background if they are requested beyond a percentage of the **`entry_cache_timeout`** value for the domain.

  Valid values for this option are **`0-99`**, and represent a percentage of the **`entry_cache_timeout`** value for each domain.

- **`entry_negative_timeout (integer)`**

  Specifies for how long (in seconds) *sssd_nss* should cache negative cache hits (that is, queries for invalid database entries, such as nonexistent ones) before asking the back end again.

- **`filter_users, filter_groups (string)`**

  Exclude certain users from being fetched from the sss NSS database. This is particularly useful for system accounts such as `root`.

- **`filter_users_in_groups (Boolean)`**

If set to **TRUE**, specifies that users listed in the **filter_users** list do not appear in group memberships when performing group lookups. If set to **FALSE**, group lookups return all users that are members of that group. If not specified, defaults to **TRUE**.

9.2.4.1.3. PAM Configuration Options

Use the following options to configure the `Pluggable Authentication Module (PAM)` service.

- **offline_credentials_expiration (integer)**

  If the authentication provider is offline, specifies for how long to allow cached log-ins (in days). This value is measured from the last successful online log-in. If not specified, defaults to **0** (no limit).

- **offline_failed_login_attempts (integer)**

  If the authentication provider is offline, specifies how many failed log in attempts are allowed. If not specified, defaults to **0** (no limit).

- **offline_failed_login_delay (integer)**

  Specifies the time in minutes after the value of **offline_failed_login_attempts** has been reached before a new log in attempt is possible.

  If set to **0**, the user cannot authenticate offline if the value of **offline_failed_login_attempts** has been reached. Only a successful online authentication can re-enable offline authentication. If not specified, defaults to **5**.

9.2.5. Configuring Domains

A domain is a database of user information. SSSD can use more than one domain at the same time, but at least one must be configured for SSSD to start. Using SSSD domains, it is possible to use several LDAP servers providing several unique namespaces. You can specify not only where users' identity information is stored, but how users authenticate against each of the specified domains.

SSSD supports the following identity and authentication combinations:

LDAP/LDAP
: This combination uses an LDAP back end as both the identity and authentication provider. For more information, refer to *Section 9.2.5.2, "Configuring an LDAP Domain"*.

LDAP/KRB5
: This combination uses an LDAP back end as the identity provider, and uses Kerberos to provide authentication. For more information, refer to *Section 9.2.6, "Setting Up Kerberos Authentication"*.

proxy
: Specifying a proxy identity or an authentication provider uses an existing NSS library or a customized PAM stack, but takes advantage of the SSSD caching mechanism. For more information, refer to *Section 9.2.7, "Configuring a Proxy Domain"*.

The following example assumes that SSSD is correctly configured and FOO is one of the domains in the **[sssd]** section. This example shows only the configuration of Kerberos authentication; it does not include any identity provider.

```
[domain/FOO]
auth_provider = krb5
krb5_server = 192.168.1.1
krb5_realm = EXAMPLE.COM
```

9.2.5.1. Domain Configuration Options

You can add new domain configurations to the **[domain/<*NAME*>]** sections of the **/etc/sssd/sssd.conf** file, and then add the list of domains to the *domains* attribute of the **[sssd]** section, in the order you want them to be queried.

9.2.5.1.1. General Domain Configuration Options

You can use the following configuration options in a domain configuration section:

- **min_id,max_id (integer)**

  Specifies the UID and GID limits for the domain. If a domain contains entries that are outside these limits, they are ignored.

  The default value for **min_id** is **1**; the default value for **max_id** is **0** (unbounded).

  Avoid conflicts with users in /etc/passwd

  If **min_id** is unspecified, it defaults to **1** for any back end. This default was chosen to provide compatibility with existing systems and to ease any migration attempts. LDAP administrators should be aware that granting identities in this range may conflict with users in the local **/etc/passwd** file. To avoid these conflicts, **min_id** should be set to **1000** or higher wherever possible.

  The **min_id** option determines the minimum acceptable value for both UID and GID numbers. Accounts with either UID or GID values below the **min_id** value are filtered out and not made available on the client.

- **enumerate (Boolean)**

  Specifies whether or not to enumerate (list) the users and groups of a domain.

  Enumeration means that the entire set of available users and groups on the remote source is cached on the local machine. When enumeration is disabled, users and groups are only cached as they are requested.

  Disable enumeration for domains with many users and groups

  If a client has enumeration enabled, reinitialization of the client results in a complete refresh of the entire set of available users and groups from the remote source. Similarly, when SSSD is connected to a new server, the entire set of available users and groups from the remote source is pulled and cached on the local machine. In a domain with a large amount of clients connected to a remote source, both aforementioned cases can affect the network performance due to frequent queries from the clients. If the set of available users and groups is large enough, it will affect the performance of clients as well. For performance reasons, it is recommended that you disable enumeration for domains with many users and groups.

The default value for this parameter is **FALSE**. Set this value to **TRUE** to enable enumeration of users and groups of a domain.

- **timeout (integer)**

  Specifies the timeout in seconds for this particular domain.

  This is used to ensure that the back end process is alive and capable of answering requests. The default value for this parameter is **10** seconds. Raising this timeout might prove useful for slower back ends, such as distant LDAP servers.

  Changing the timeout value to 0

  If you set **timeout = 0**, SSSD reverts to the default value; you cannot force a timeout value of zero, because this would force the `sssd` daemon into a loop.

- **cache_credentials (Boolean)**

  Specifies whether or not to store user credentials in the local SSSD domain database cache.

  The default value for this parameter is **FALSE**. You should set this value to **TRUE** for domains other than local if you want to enable offline authentication.

- **id_provider (string)**

  Specifies the data provider identity back end to use for this domain. Currently supported identity back ends are:
  - proxy — Support a legacy NSS provider (for example, *nss_nis*).

    Changing the id_provider value to proxy

    SSSD needs to know which legacy NSS library to load in order to start successfully. If you set **id_provider** to **proxy**, ensure that you also specify a value for **proxy_lib_name**. Refer to *Section 9.2.7, "Configuring a Proxy Domain"* for information on this attribute.

  - local — SSSD internal local provider.
  - ldap — LDAP provider.

- **entry_cache_timeout (integer)**

  Specifies for how long the domain's data provider should cache positive cache hits (that is, queries for valid database entries) before asking the database again.

- **use_fully_qualified_names (Boolean)**

  Specifies whether or not requests to this domain require fully-qualified domain names.

If set to **TRUE**, all requests to this domain must use fully-qualified domain names. It also means that the output from the request displays the fully-qualified name.

The ability to restrict requests in this way means that if you know you have multiple domains with conflicting usernames, then there is no doubt about which username the query will resolve.

Consider the following examples, in which the IPA domain database contains a user named `ipauser01`, and the *`use_fully_qualified_names`* attribute is set to **TRUE**:

```
# getent passwd ipauser01
[no output]
# getent passwd ipauser01@IPA
ipauser01@IPA:x:937315651:937315651:ipauser01:/home/ipauser01:/bin/sh
```

In the following examples, using the same IPA domain and user, the *`use_fully_qualified_names`* attribute is set to **FALSE**:

```
# getent passwd ipauser01
ipauser01:x:937315651:937315651:ipauser01:/home/ipauser01:/bin/sh
# getent passwd ipauser01@IPA
ipauser01:x:937315651:937315651:ipauser01:/home/ipauser01:/bin/sh
```



Changing the use_fully_qualified_names value to FALSE

If *`use_fully_qualified_names`* is set to **FALSE**, you can continue to use the fully-qualified name in your requests, but only the simplified version is displayed in the output.

SSSD can only parse `name@domain`, not `name@realm`. You can, however, use the same name for both your domain and your realm.

- **`auth_provider (string)`**

  The authentication provider used for the domain. The default value for this option is the value of **`id_provider`** if it is set and can handle authentication requests.

  Currently supported authentication providers are:
  - ldap — for native LDAP authentication. Refer to the sssd-ldap(5) manual page for more information on configuring LDAP.
  - krb5 — for Kerberos authentication. Refer to the sssd-krb5(5) manual page for more information on configuring Kerberos.
  - proxy — for relaying authentication to some other PAM target.
  - none — explicitly disables authentication.

9.2.5.1.2. Proxy Configuration Options

- **`proxy_pam_target`** (string)

This option is only used when the **auth_provider** option is set to **proxy**, and specifies the target to which PAM must proxy.

This option has no default value. If proxy authentication is required, you need to specify your own PAM target. This corresponds to a file containing PAM stack information in the system's default PAM configuration directory. On Fedora-based systems, this is the **/etc/pam.d/** directory.



Avoid recursive inclusion of pam_sss

Ensure that your proxy PAM stack does *not* recursively include **pam_sss.so**.

- **proxy_lib_name** (string)

  This option is only used when the **id_provider** option is set to **proxy**, and specifies which existing NSS library to proxy identity requests through.

  This option has no default value. You need to manually specify an existing library to take advantage of this option. For example, set this value to **nis** to use the existing **libnss_nis.so** file.

9.2.5.2. Configuring an LDAP Domain

An LDAP domain is one where the **id_provider** option is set to **ldap** (**id_provider = ldap**). Such a domain requires a running LDAP server against which to authenticate. This can be an open source LDAP server such as OpenLDAP or Microsoft Active Directory. SSSD currently supports Microsoft Active Directory 2003 (+Services for UNIX) and Active Directory 2008 (+Subsystem for UNIX-based Applications). In all cases, the client configuration is stored in the **/etc/sssd/sssd.conf** file.

How to Authenticate Against an LDAP Server

SSSD does not support authentication over an unencrypted channel. Consequently, if you want to authenticate against an LDAP server, either TLS/SSL or LDAPS is required. If the LDAP server is used only as an identity provider, an encrypted channel is not needed.

Edit your **/etc/sssd/sssd.conf** file to include the following settings:

```
# A native LDAP domain
[domain/LDAP]
enumerate = false
cache_credentials = TRUE

id_provider = ldap
auth_provider = ldap
ldap_schema = rfc2307
chpass_provider = ldap

ldap_uri = ldap://ldap.mydomain.org
ldap_search_base = dc=mydomain,dc=org
ldap_tls_reqcert = demand
ldap_tls_cacert = /etc/pki/tls/certs/ca-bundle.crt
```

Creating a certificate with an IP address instead of the server name

If you wish to use an IP address in the **ldap_uri** option instead of the server name, for example, if GSSAPI is used to avoid time consuming DNS lookups, the TSL/SSL setup might fail. This is due to th
addr
certi
The I

1. Using your command line, execute the following command to convert an existing certificate previously signed by the *key.pem* key into a certificate request.

```
openssl x509 -x509toreq -in old_cert.pem -out req.pem -signkey old_cert.pem
```

~~openssl x509 -x509toreq -in old_cert.pem -out req.pem -signkey key.pem~~ the following command:

2. Edit your **/etc/pki/tls/openssl.cnf** configuration file to include the following line under the *[v3_ca]* section:
   Replace the IP address with one of your choice.

```
subjectAltName = IP:10.0.0.10
```

3. By executing the following command, use the previously generated certificate request to generate a new self-signed certificate that will contain your desired IP address:

```
openssl x509 -req -in req.pem -out new_cert.pem -extfile ./openssl.cnf -extensions
v3_ca -signkey old_cert.pem
```

   where:

   - The **openssl x509** command creates the new certificate.
   - The **-req** option tells the command to expect a certificate request as an input.
   - The **-in** and **-out** options specify the input and output files.
   - The **-extfile** option expects a file containing certificate extensions to use (in our case the **subjectAltName** extension).
   - The **-extensions** option specifies the section of the **openssl.cnf** file to add certificate extensions from (in this case, the *[v3_ca]* section).
   - The **-signkey** option tells the command to self-sign the input file using the supplied private key.

   For more information on the **x509** utility and its parameters, refer to **man x509**.

4. Lastly, copy the private key block from the **old_cert.pem** file into the **new_cert.pem** file to keep all relevant information in one file.

It is advisable to use a Certificate Authority to issue your certificate. Consider using the Red Hat Certificate System; for more information on managing subject names and subject alternative names in your certificate, refer to the *Red Hat Certificate System Admin Guide*[3].

When creating a certificate through the **certutil** utility provided by the *nss-utils* package, note that **certutil** supports DNS subject alternative names for certificate creation only.

[3] http://docs.redhat.com/docs/en-US/Red_Hat_Certificate_System/8.0/html/Admin_Guide/Managing_Subject_Names_and_Subject_Alternative_Names.html

Selecting an LDAP Schema

You can set the *ldap_schema* attribute to either **rfc2307** or **rfc2307bis**. These schema define how groups in LDAP are specified. In *RFC 2307*, group objects use a multi-valued attribute, *memberuid*, which lists the names of the users that belong to that group. In *RFC 2307bis*, instead of the *memberuid*, group objects use the *member* attribute. Rather than just the name of the user, this attribute contains the full Distinguished Name (DN) of another object in the LDAP database. This means that groups can have other groups as members. That is, it adds support for nested groups.

SSSD assumes that your LDAP server is using *RFC 2307*. If your LDAP server is using *RFC 2307bis*, and you do not update the **/etc/sssd/sssd.conf** file accordingly, this can impact how your users and groups are displayed. It also means that some groups will not be available and network resources may be inaccessible even though you have permissions to use them.

For example, when using *RFC 2307bis* and you have configured both primary and secondary groups, or are using nested groups, you can use the **id** command to display these groups:

```
[f12server@ipaserver ~]$ id
uid=500(f12server) gid=500(f12server) groups=500(f12server),510(f12tester)
```

If instead you have configured your client to use *RFC 2307* then only the primary group is displayed.

Changes to this setting only affect how SSSD determines the groups to which a user belongs; there is no negative effect on the actual user data. If you do not know the correct value for this attribute, consult your System Administrator.

Specifying Timeout Values

SSSD supports a number of timeout values that apply when configuring an LDAP domain. These are described below.

- **ldap_search_timeout (integer)** — Specifies the timeout (in seconds) that LDAP searches are allowed to run before they are canceled and cached results are returned (and offline mode is entered). If not specified:

  Defaults to five when **enumerate** = **False**

  Defaults to 30 when **enumerate** = **True**. This option is forced to a minimum of 30 in this case.

  The ldap_network_timeout option is going to be changed

  This option is subject to change in future versions of SSSD, where it may be replaced by a series of timeouts for specific look-up types.

- **ldap_network_timeout (integer)** — Specifies the timeout (in seconds) after which the `poll(2)`/`select(2)` following a `connect(2)` returns in case of no activity.

  If not specified, defaults to five.

- **ldap_opt_timeout (integer)** — Specifies the timeout (in seconds) after which calls to synchronous LDAP APIs will abort if no response is received. This option also controls the timeout when communicating with the KDC in case of a SASL bind.

If not specified, defaults to five.



DNS Service Discovery

The DNS service discovery feature allows the LDAP back end to automatically find the appropriate DNS servers to connect to using a special DNS query. For more information on the DNS service discovery feature, refer to *Section 9.2.3.2.4.1, "Using SRV Records with Failover"*.

9.2.5.3. Configuring a Microsoft Active Directory Domain

You can configure SSSD to use Microsoft Active Directory as an LDAP back end, providing both identity and authentication services. If you are using Active Directory 2003, SSSD requires that you install Windows Services for UNIX (SFU) on the machine where Active Directory is installed. If instead you are using Active Directory 2008, you need to install the Subsystem for UNIX-based Applications (SUA) on the Active Directory machine.



SFU is not supported on 64-bit systems

SFU is not supported on 64-bit operating systems. Refer to *http://support.microsoft.com/kb/920751* for more information about which Windows systems can provide a suitable platform for an SSSD LDAP back end.

9.2.5.3.1. Configuring Active Directory 2003 as an LDAP Back End

The example **/etc/sssd/sssd.conf** file that ships with SSSD contains the following sample configuration for Active Directory 2003:

```
# Example LDAP domain where the LDAP server is an Active Directory 2003 server.

[domain/AD]
description = LDAP domain with AD server
enumerate = false
min_id = 1000
;
id_provider = ldap
auth_provider = ldap
ldap_uri = ldap://your.ad.server.com
ldap_schema = rfc2307bis
ldap_search_base = dc=example,dc=com
ldap_default_bind_dn = cn=Administrator,cn=Users,dc=example,dc=com
ldap_default_authtok_type = password
ldap_default_authtok = YOUR_PASSWORD
ldap_user_object_class = person
ldap_user_name = msSFU30Name
ldap_user_uid_number = msSFU30UidNumber
ldap_user_gid_number = msSFU30GidNumber
ldap_user_home_directory = msSFU30HomeDirectory
ldap_user_shell = msSFU30LoginShell
ldap_user_principal = userPrincipalName
ldap_group_object_class = group
```

```
ldap_group_name = msSFU30Name
ldap_group_gid_number = msSFU30GidNumber
```

This configuration is specific to Windows Active Directory 2003. Refer to *Section 9.2.5.3.2, "Configuring Active Directory 2003 R2 and 2008 as LDAP Back Ends"* for information on how to configure Active Directory 2003 R2 and Active Directory 2008.

Note that the above configuration assumes that the certificates are stored in the default location (that is, in **`/etc/openldap/cacerts`**) and that the `c_rehash` function has been used to create the appropriate symlinks.

More Information

Refer to the *sssd-ldap(5)* manual page for a full description of all the options that apply to LDAP domains.

9.2.5.3.2. Configuring Active Directory 2003 R2 and 2008 as LDAP Back Ends

The configuration of **`/etc/sssd/sssd.conf`** to support Active Directory 2003 R2 or Active Directory 2008 as a back end is similar to that for AD 2003. The following example configuration highlights the necessary changes.

```
# Example LDAP domain where the LDAP server is an Active Directory 2003 R2 or an Active
 Directory 2008 server.

[domain/AD]
description = LDAP domain with AD server
; debug_level = 9
enumerate = false

id_provider = ldap
auth_provider = ldap
chpass_provider = ldap

ldap_uri = ldap://your.ad.server.com
ldap_tls_cacertdir = /etc/openldap/cacerts
ldap_tls_cacert = /etc/openldap/cacerts/test.cer
ldap_search_base = dc=example,dc=com
ldap_default_bind_dn = cn=Administrator,cn=Users,dc=example,dc=com
ldap_default_authtok_type = password
ldap_default_authtok = YOUR_PASSWORD
ldap_pwd_policy = none
ldap_user_object_class = user
ldap_group_object_class = group
```

Note that the above configuration assumes that the certificates are stored in the default location (that is, in **`/etc/openldap/cacerts`**) and that the `c_rehash` function has been used to create the appropriate symlinks.

9.2.6. Setting Up Kerberos Authentication

In order to set up Kerberos authentication, you need to know the address of your *key distribution center* (KDC) and the Kerberos domain. The client configuration is then stored in the **`/etc/sssd/sssd.conf`** file.

The Kerberos 5 authentication back end does not contain an identity provider and must be paired with one in order to function properly (for example, **`id_provider = ldap`**). Some information required by the Kerberos 5 authentication back end must be supplied by the identity provider, such as the user's *Kerberos Principal Name* (UPN). The identity provider configuration should contain an entry to specify

this UPN. Refer to the manual page for the applicable identity provider for details on how to configure the UPN.

If the UPN is not available in the identity back end, SSSD will construct a UPN using the format `username@krb5_realm`.

SSSD assumes that the Kerberos KDC is also a Kerberos kadmin server. However, it is very common for production environments to have multiple, read-only replicas of the KDC, but only a single kadmin server (because password changes and similar procedures are comparatively rare). To manage this type of configuration, you can use the **`krb5_kpasswd`** option to specify where your password changing service is running, or if it is running on a non-default port. If the **`krb5_kpasswd`** option is not defined, SSSD tries to use the Kerberos KDC in order to change the password. Refer to the *sssd-krb5(5)* manual page for more information about this and all Kerberos configuration options.

How to Set Up Kerberos Authentication

Edit your **`/etc/sssd/sssd.conf`** file to include the following settings:

```
# A domain with identities provided by LDAP and authentication by Kerberos
[domain/KRBDOMAIN]
enumerate = false
id_provider = ldap
chpass_provider = krb5
ldap_uri = ldap://ldap.mydomain.org
ldap_search_base = dc=mydomain,dc=org
tls_reqcert = demand
ldap_tls_cacert = /etc/pki/tls/certs/ca-bundle.crt

auth_provider = krb5
krb5_server = 192.168.1.1
krb5_realm = EXAMPLE.COM
krb5_changepw_principal = kadmin/changepw
krb5_ccachedir = /tmp
krb5_ccname_template = FILE:%d/krb5cc_%U_XXXXXX
krb5_auth_timeout = 15
```

This example describes the minimum options that must be configured when using Kerberos authentication. Refer to the *sssd-krb5(5)* manual page for a full description of all the options that apply to configuring Kerberos authentication.



DNS Service Discovery

The DNS service discovery feature allows the Kerberos 5 authentication back end to automatically find the appropriate DNS servers to connect to using a special DNS query. For more information on the DNS service discovery feature, refer to *Section 9.2.3.2.4.1, “Using SRV Records with Failover”*.

9.2.6.1. Setting up SASL/GSSAPI Authentication

GSSAPI (Generic Security Services Application Programming Interface) is a supported *SASL* (Simple Authentication and Security Layer) authentication method. Kerberos is currently the only commonly used GSSAPI implementation. An LDAP client and an LDAP server use SASL to take advantage of GSSAPI as the authentication method (an alternative to plain text passwords, etc.). The GSSAPI plug-in for SASL is then invoked on the client and server side to use Kerberos to communicate.

Using GSSAPI protected communication for LDAP is an advanced configuration not supported by the Authentication Configuration tool; the following steps show how to manually configure it.

On the KDC

1. Using **kadmin**, set up a Kerberos service principal for the directory server. Use the **-randkey** option for the **kadmin**'s **addprinc** command to create the principal and assign it a random key:

```
kadmin: addprinc -randkey ldap/server.example.com
```

2. Use the **ktadd** command to write the service principal to a file:

```
kadmin: ktadd -k /root/ldap.keytab ldap/server.example.com
```

3. Using **kadmin**, set up a Kerberos host principal for the client running SSSD. Use the **-randkey** option for the **kadmin**'s **addprinc** command to create the principal and assign it a random key:

```
kadmin: addprinc -randkey host/client.example.com
```

4. Use the **ktadd** command to write the host principal to a file:

```
kadmin: ktadd -k /root/client.keytab host/client.example.com
```

On the Directory Server

Complete the following steps for a directory server of your choice:

OpenLDAP

1. Copy the previously created **/root/ldap.keytab** file from the KDC to the **/etc/openldap/** directory and name it **ldap.keytab**.

2. Make the **/etc/openldap/ldap.keytab** file read-writable for the `ldap` user and readable for the `ldap` group only.

Red Hat Directory Server

1. Copy the previously created **/root/ldap.keytab** file from the KDC to the **/etc/dirsrv/** directory and name it **ldap.keytab**.

2. Uncomment the `KRB5_KTNAME` line in the **/etc/sysconfig/dirsrv** (or instance-specific) file, and set the keytab location for the `KRB5_KTNAME` variable. For example:

```
# In order to use SASL/GSSAPI the directory
# server needs to know where to find its keytab
# file - uncomment the following line and set
# the path and filename appropriately
KRB5_KTNAME=/etc/dirsrv/ldap.keytab; export KRB5_KTNAME
```

On the Client

1. Copy the previously created **/root/client.keytab** file from the KDC to the **/etc/** directory and name it **krb5.keytab**. If the **/etc/krb5.keytab** file exists already, use the **ktutil** utility to merge both files properly. For more information on the **ktutil** utility, refer to **man ktutil**.

2. Modify your /etc/sssd/sssd.conf file to include the following settings:

```
ldap_sasl_mech = gssapi
ldap_sasl_authid = host/client.example.com@EXAMPLE.COM
ldap_krb5_keytab = /etc/krb5.keytab (default)
ldap_krb5_init_creds = true (default)
ldap_krb5_ticket_lifetime = 86400 (default)
krb5_realm = EXAMPLE.COM
```

9.2.7. Configuring a Proxy Domain

SSSD currently only supports LDAP and Kerberos as authentication providers. If you prefer to use SSSD (for example, to take advantage of its caching functionality), but SSSD does not support your authentication method, you can set up a proxy authentication provider. This could be the case if you use fingerprint scanners or smart cards as part of your authentication process. Similarly, you can set up proxy to serve as an identity provider.

The following sections cover combinations of identity and authentication providers in which the proxy server takes the role of one.

9.2.7.1. proxy/KRB5

The following configuration is an example of a combination of a proxy identity provider used with Kerberos authentication:

Edit the **`/etc/sssd/sssd.conf`** configuration file to include the following settings:

```
[domain/PROXY_KRB5]
auth_provider = krb5
krb5_server = 192.168.1.1
krb5_realm = EXAMPLE.COM

id_provider = proxy
proxy_lib_name = nis
enumerate = true
cache_credentials = true
```

For more information on various Kerberos configuration options, refer to *Section 9.2.6, "Setting Up Kerberos Authentication"*.

9.2.7.2. LDAP/proxy

An example of a combination of an LDAP identity provider and a proxy authentication provider is the use of the LDAP with a custom PAM stack. To enable authentication via the PAM stack, complete the following steps:

1. Edit the **`/etc/sssd/sssd.conf`** configuration file to include the following settings:

```
[domain/LDAP_PROXY]
id_provider = ldap
ldap_uri = ldap://example.com
ldap_search_base = dc=example,dc=com
```

```
auth_provider = proxy
proxy_pam_target = sssdpamproxy
enumerate = true
cache_credentials = true
```

By specifying the options above, authentication requests will be proxied via the **/etc/pam.d/sssdpamproxy** file which provides the needed module interfaces. Note that the **pam_ldap.so** file can be substituted with a PAM module of your choice.

For more information on various LDAP configuration options, refer to *Section 9.2.5.2, "Configuring an LDAP Domain"*.

2. Create a **/etc/pam.d/sssdpamproxy** file (if not already created) and specify the following settings in it:

```
auth          required      pam_ldap.so
account       required      pam_ldap.so
password      required      pam_ldap.so
session       required      pam_ldap.so
```

9.2.7.3. proxy/proxy

An example of a combination of an proxy identity provider and a proxy authentication provider is the use of the proxy identity provider with a custom PAM stack. To enable authentication via the PAM stack, complete the following steps:



Make sure the nss-pam-ldapd package is installed

In order to use the proxy identity provider, you must have the *nss-pam-ldapd* package installed.

1. Edit the **/etc/sssd/sssd.conf** configuration file to include the following settings:

```
[domain/PROXY_PROXY]
auth_provider = proxy
id_provider = proxy
proxy_lib_name = ldap
proxy_pam_target = sssdproxyldap
enumerate = true
cache_credentials = true
```

By specifying the options above, authentication requests will be proxied via the **/etc/pam.d/sssdproxyldap** file which provides the needed module interfaces.

For more information on the options used in the configuration example above, refer to **man sssd.conf**

2. Create a **/etc/pam.d/sssdproxyldap** file (if not already created) and specify the following settings in it:

```
auth          required      pam_ldap.so
account       required      pam_ldap.so
```

```
password      required      pam_ldap.so
session       required      pam_ldap.so
```

3. Edit the **/etc/nslcd.conf** file (the default configuration file for the LDAP name service daemon) to include the following settings:

```
uid nslcd
gid ldap
uri ldaps://ldap.mydomain.org:636
base dc=mydomain,dc=org
ssl on
tls_cacertdir /etc/openldap/cacerts
```

For more information on the options used in the configuration example above, refer to **man nslcd.conf**

9.2.8. Troubleshooting

This section lists some of the issues you may encounter when implementing SSSD, the possible causes of these issues, and how to resolve them. If you find further issues that are not covered here, refer to the *We Need Feedback* section in the *Preface* for information on how to file a bug report.

9.2.8.1. Using SSSD Log Files

SSSD uses a number of log files to report information about its operation, and this information can help to resolve issues in the event of SSSD failure or unexpected behavior. The default location for these log files on Fedora—based systems is the **/var/log/sssd/** directory.

SSSD produces a log file for each back end (that is, one log file for each domain specified in the **/etc/sssd/sssd.conf** file), as well as an **sssd_pam.log** and an **sssd_nss.log** file. This level of granularity can help you to quickly isolate and resolve any errors or issues you might experience with SSSD.

You should also examine the **/var/log/secure** file, which logs authentication failures and the reason for the failure. For example, if you see Reason 4: System Error reported against any failure, you should increase the debug level of the log files.

Producing More Verbose Log Files

If you are unable to identify and resolve any problems with SSSD after inspection of the default log files, you can configure SSSD to produce more verbose files. You can set the **debug_level** option in the **/etc/sssd/sssd.conf** for the domain that is causing concern, and then restart SSSD. Refer to the *sssd.conf(5)* manual page for more information on how to set the **debug_level** for a specific domain.

All log files include timestamps on debug messages by default. This can make it easier to understand any errors that may occur, why they occurred, and how to address them. If necessary, you can disable these timestamps by setting the appropriate parameter to **FALSE** in the **/etc/sssd/sssd.conf** file:

```
--debug-timestamps=FALSE
```

9.2.8.2. Problems with SSSD Configuration

- SSSD fails to start

- SSSD requires at least one properly configured domain before the service will start. Without such a domain, you might see the following error message when trying to start SSSD with the following command:

  # sssd -d4

  ```
  [sssd] [ldb] (3): server_sort:Unable to register control with rootdse!

  [sssd] [confdb_get_domains] (0): No domains configured, fatal error!
  [sssd] [get_monitor_config] (0): No domains configured.
  ```

  You can ignore the "Unable to register control with rootdse!" message, as it is erroneous. The other messages, however, indicate that SSSD is unable to locate any properly configured domains.

  Edit your **/etc/sssd/sssd.conf** file and ensure you have at least one properly configured domain, and then try to start SSSD.

- SSSD requires at least one available service provider before it will start. With no available service providers, you might see the following error message when trying to start SSSD with the following command:

  # sssd -d4

  ```
  [sssd] [ldb] (3): server_sort:Unable to register control with rootdse!

  [sssd] [get_monitor_config] (0): No services configured!
  ```

  You can ignore the "Unable to register control with rootdse!" message, as it is erroneous. The other message, however, indicates that SSSD is unable to locate any available service providers.

  Edit your **/etc/sssd/sssd.conf** file and ensure you have at least one available service providers, and then try to start SSSD.

  Configuring the service providers

  SSSD requires that service providers be configured as a comma-separated list in a single *services* entry in the **/etc/sssd/sssd.conf** file. If services are listed in multiple entries, only the last entry is recognized by SSSD.

- Refer to the *sssd.conf(5)* manual page for more options that might assist in troubleshooting issues with SSSD.

9.2.8.3. Problems with SSSD Service Configuration

9.2.8.3.1. Problems with NSS

This section describes some common problems with NSS, their symptoms, and how to resolve them.

- NSS fails to return user information

- Ensure that NSS is running

  # systemctl is-active sssd.service

  This command should return results similar to the following:

  ```
  sssd (pid 21762) is running...
  ```

- Ensure that you have correctly configured the **[nss]** section of the **/etc/sssd/sssd.conf** file. For example, ensure that you have not misconfigured the *filter_users* or *filter_groups* attributes. Refer to the *NSS configuration options* section of the *sssd.conf(5)* manual page for information on how to configure these attributes.

- Ensure that you have included nss in the list of services that sssd should start

- Ensure that you have correctly configured the **/etc/nsswitch.conf** file. Refer to the section *Section 9.2.3.2.1, "Configuring NSS"* for information on how to correctly configure this file.

9.2.8.3.2. Problems with PAM

This section describes some common problems with PAM, their symptoms, and how to resolve them.

- Setting the password for the local SSSD user prompts twice for the password

  When attempting to change a local SSSD user's password, you might see output similar to the following:

  ```
  [root@clientF11 tmp]# passwd user1000
  Changing password for user user1000.
  New password:
  Retype new password:
  New Password:
  Reenter new Password:
  passwd: all authentication tokens updated successfully.
  ```

  This is the result of an incorrect PAM configuration. Refer to *Section 9.2.3.2.2, "Configuring PAM"*, and ensure that the *use_authtok* option is correctly configured in your **/etc/pam.d/system-auth** file.

9.2.8.3.3. Problems with NFS and NSCD

SSSD is not designed to be used with the nscd daemon, and will likely generate warnings in the SSSD log files. Even though SSSD does not directly conflict with nscd, the use of both at the same time can result in unexpected behavior (specifically with how long entries are being cached).

If you are using Network Manager to manage your network connections, it may take several minutes for the network interface to come up. During this time, various services will attempt to start. If these services start before the network is up (that is, the DNS servers cannot yet be reached) they will fail to identify the forward or reverse DNS entries they might need. These services will be reading an incorrect or possibly empty **resolv.conf** file. This file is typically only read once, and so any changes made to this file are not automatically applied.

This can result in the failure of some system services, and in particular can cause NFS locking to fail on the machine where the nscd service is running, unless that service is manually restarted.

One method of working around this problem is to enable caching for *hosts* and *services* in the **/etc/nscd.conf** file, and to rely on the SSSD cache for the *passwd* and *group* entries. With nscd

answering *hosts* and *services* requests, these entries would have been cached and returned by nscd during the boot process.



NSCD and later versions of SSSD

Later versions of SSSD should negate any need for NSCD.

9.2.8.4. Problems with SSSD Domain Configuration

- NSS returns incorrect user information
  - If your search for user information returns incorrect data, ensure that you do not have conflicting usernames in separate domains. If you use multiple domains, it is recommended that you set the *use_fully_qualified_domains* attribute to **TRUE** in the **/etc/sssd/sssd.conf** file.

9.2.8.5. Additional Resources

9.2.8.5.1. Manual Pages

SSSD ships with a number of manual pages, all of which provide additional information about specific aspects of SSSD, such as configuration files, commands, and available options. SSSD currently provides the following manual pages:

- **sssd.conf(5)**
- **sssd-ipa(5)**
- **sssd-krb5(5)**
- **sssd-ldap(5)**
- **sssd(8)**
- **sssd_krb5_locator_plugin(8)**
- **pam_sss(8)**

You should refer to these manual pages for detailed information about all aspects of SSSD, its configuration, and associated tools and commands.

9.2.8.5.2. Mailing Lists

You can subscribe to the SSSD mailing list to follow and become involved in the development of SSSD, or to ask questions about any issues you may be experiencing with your SSSD deployment.

Visit *https://fedorahosted.org/mailman/listinfo/sssd-devel* to subscribe to this mailing list.

9.2.9. SSSD Configuration File Format

The following listing describes the current version (Version 2) of the SSSD configuration file format.

```
[sssd]
config_file_version = 2
services = nss, pam
```

```
domains = mybox.example.com, ldap.example.com, ipa.example.com, nis.example.com
# sbus_timeout = 300

[nss]
nss_filter_groups = root
nss_filter_users = root
nss_entry_cache_timeout = 30
nss_enum_cache_timeout = 30

[domain/mybox.example.com]
domain_type = local
enumerate = true
min_id = 1000
# max_id = 2000

local_default_shell = /bin/bash
local_default_homedir = /home

# Possible overrides
# id_provider = local
# auth_provider = local
# authz_provider = local
# passwd_provider = local

[domain/ldap.example.com]
domain_type = ldap
server = ldap.example.com, ldap3.example.com, 10.0.0.2
# ldap_uri = ldaps://ldap.example.com:9093
# ldap_use_tls = ssl
ldap_search_base = dc=ldap,dc=example,dc=com
enumerate = false

# Possible overrides
# id_provider = ldap
# id_server = ldap2.example.com
# auth_provider = krb5
# auth_server = krb5.example.com
# krb5_realm = KRB5.EXAMPLE.COM

[domain/ipa.example.com]
domain_type = ipa
server = ipa.example.com, ipa2.example.com
enumerate = false

# Possible overrides
# id_provider = ldap
# id_server = ldap2.example.com
# auth_provider = krb5
# auth_server = krb5.example.com
# krb5_realm = KRB5.EXAMPLE.COM

[domain/nis.example.com]
id_provider = proxy
proxy_lib = nis
auth_provider = proxy
proxy_auth_target = nis_pam_proxy
```

OpenSSH

SSH (Secure Shell) is a protocol which facilitates secure communications between two systems using a client/server architecture and allows users to log into server host systems remotely. Unlike other remote communication protocols, such as FTP or Telnet, SSH encrypts the login session, rendering the connection difficult for intruders to collect unencrypted passwords.

The **ssh** program is designed to replace older, less secure terminal applications used to log into remote hosts, such as **telnet** or **rsh**. A related program called **scp** replaces older programs designed to copy files between hosts, such as **rcp**. Because these older applications do not encrypt passwords transmitted between the client and the server, avoid them whenever possible. Using secure methods to log into remote systems decreases the risks for both the client system and the remote host.

Fedora includes the general OpenSSH package (*openssh*) as well as the OpenSSH server (*openssh-server*) and client (*openssh-clients*) packages. Note that the OpenSSH packages require the OpenSSL package (*openssl*), which installs several important cryptographic libraries, enabling OpenSSH to provide encrypted communications.

10.1. The SSH Protocol

10.1.1. Why Use SSH?

Potential intruders have a variety of tools at their disposal enabling them to disrupt, intercept, and re-route network traffic in an effort to gain access to a system. In general terms, these threats can be categorized as follows:

Interception of communication between two systems
: The attacker can be somewhere on the network between the communicating parties, copying any information passed between them. He may intercept and keep the information, or alter the information and send it on to the intended recipient.

  This attack is usually performed using a *packet sniffer*, a rather common network utility that captures each packet flowing through the network, and analyzes its content.

Impersonation of a particular host
: Attacker's system is configured to pose as the intended recipient of a transmission. If this strategy works, the user's system remains unaware that it is communicating with the wrong host.

  This attack can be performed using a technique known as *DNS poisoning*, or via so-called *IP spoofing*. In the first case, the intruder uses a cracked DNS server to point client systems to a maliciously duplicated host. In the second case, the intruder sends falsified network packets that appear to be from a trusted host.

Both techniques intercept potentially sensitive information and, if the interception is made for hostile reasons, the results can be disastrous. If SSH is used for remote shell login and file copying, these security threats can be greatly diminished. This is because the SSH client and server use digital signatures to verify their identity. Additionally, all communication between the client and server systems is encrypted. Attempts to spoof the identity of either side of a communication does not work, since each packet is encrypted using a key known only by the local and remote systems.

10.1.2. Main Features

The SSH protocol provides the following safeguards:

No one can pose as the intended server
: After an initial connection, the client can verify that it is connecting to the same server it had connected to previously.

No one can capture the authentication information
: The client transmits its authentication information to the server using strong, 128-bit encryption.

No one can intercept the communication
: All data sent and received during a session is transferred using 128-bit encryption, making intercepted transmissions extremely difficult to decrypt and read.

Additionally, it also offers the following options:

It provides secure means to use graphical applications over a network
: Using a technique called *X11 forwarding*, the client can forward *X11* (*X Window System*) applications from the server.

It provides a way to secure otherwise insecure protocols
: The SSH protocol encrypts everything it sends and receives. Using a technique called *port forwarding*, an SSH server can become a conduit to securing otherwise insecure protocols, like POP, and increasing overall system and data security.

It can be used to create a secure channel
: The OpenSSH server and client can be configured to create a tunnel similar to a virtual private network for traffic between server and client machines.

It supports the Kerberos authentication
: OpenSSH servers and clients can be configured to authenticate using the GSSAPI (Generic Security Services Application Program Interface) implementation of the Kerberos network authentication protocol.

10.1.3. Protocol Versions

Two varieties of SSH currently exist: version 1, and newer version 2. The OpenSSH suite under Fedora uses SSH version 2, which has an enhanced key exchange algorithm not vulnerable to the known exploit in version 1. However, for compatibility reasons, the OpenSSH suite does support version 1 connections as well.



Avoid using SSH version 1

To ensure maximum security for your connection, it is recommended that only SSH version 2-compatible servers and clients are used whenever possible.

10.1.4. Event Sequence of an SSH Connection

The following series of events help protect the integrity of SSH communication between two hosts.

1. A cryptographic handshake is made so that the client can verify that it is communicating with the correct server.
2. The transport layer of the connection between the client and remote host is encrypted using a symmetric cipher.
3. The client authenticates itself to the server.
4. The remote client interacts with the remote host over the encrypted connection.

10.1.4.1. Transport Layer

The primary role of the transport layer is to facilitate safe and secure communication between the two hosts at the time of authentication and during subsequent communication. The transport layer accomplishes this by handling the encryption and decryption of data, and by providing integrity protection of data packets as they are sent and received. The transport layer also provides compression, speeding the transfer of information.

Once an SSH client contacts a server, key information is exchanged so that the two systems can correctly construct the transport layer. The following steps occur during this exchange:

- Keys are exchanged
- The public key encryption algorithm is determined
- The symmetric encryption algorithm is determined
- The message authentication algorithm is determined
- The hash algorithm is determined

During the key exchange, the server identifies itself to the client with a unique *host key*. If the client has never communicated with this particular server before, the server's host key is unknown to the client and it does not connect. OpenSSH gets around this problem by accepting the server's host key. This is done after the user is notified and has both accepted and verified the new host key. In subsequent connections, the server's host key is checked against the saved version on the client, providing confidence that the client is indeed communicating with the intended server. If, in the future, the host key no longer matches, the user must remove the client's saved version before a connection can occur.



Always verify the integrity of a new SSH server

It is possible for an attacker to masquerade as an SSH server during the initial contact since the local system does not know the difference between the intended server and a false one set up by an attacker. To help prevent this, verify the integrity of a new SSH server by contacting the server administrator before connecting for the first time or in the event of a host key mismatch.

SSH is designed to work with almost any kind of public key algorithm or encoding format. After an initial key exchange creates a hash value used for exchanges and a shared secret value, the two systems immediately begin calculating new keys and algorithms to protect authentication and future data sent over the connection.

After a certain amount of data has been transmitted using a given key and algorithm (the exact amount depends on the SSH implementation), another key exchange occurs, generating another set of hash values and a new shared secret value. Even if an attacker is able to determine the hash and shared secret value, this information is only useful for a limited period of time.

10.1.4.2. Authentication

Once the transport layer has constructed a secure tunnel to pass information between the two systems, the server tells the client the different authentication methods supported, such as using a private key-encoded signature or typing a password. The client then tries to authenticate itself to the server using one of these supported methods.

SSH servers and clients can be configured to allow different types of authentication, which gives each side the optimal amount of control. The server can decide which encryption methods it supports based on its security model, and the client can choose the order of authentication methods to attempt from the available options.

10.1.4.3. Channels

After a successful authentication over the SSH transport layer, multiple channels are opened via a technique called *multiplexing*[1]. Each of these channels handles communication for different terminal sessions and for forwarded X11 sessions.

Both clients and servers can create a new channel. Each channel is then assigned a different number on each end of the connection. When the client attempts to open a new channel, the clients sends the channel number along with the request. This information is stored by the server and is used to direct communication to that channel. This is done so that different types of sessions do not affect one another and so that when a given session ends, its channel can be closed without disrupting the primary SSH connection.

Channels also support *flow-control*, which allows them to send and receive data in an orderly fashion. In this way, data is not sent over the channel until the client receives a message that the channel is open.

The client and server negotiate the characteristics of each channel automatically, depending on the type of service the client requests and the way the user is connected to the network. This allows great flexibility in handling different types of remote connections without having to change the basic infrastructure of the protocol.

10.2. An OpenSSH Configuration

In order to perform tasks described in this section, you must have superuser privileges. To obtain them, log in as `root` by typing:

```
su -
```

10.2.1. Configuration Files

[1] A multiplexed connection consists of several signals being sent over a shared, common medium. With SSH, different channels are sent over a common secure connection.

There are two different sets of configuration files: those for client programs (that is, **ssh**, **scp**, and **sftp**), and those for the server (the **sshd** daemon).

System-wide SSH configuration information is stored in the **/etc/ssh/** directory. See *Table 10.1, "System-wide configuration files"* for a description of its content.

Table 10.1. System-wide configuration files

Configuration File	Description
/etc/ssh/moduli	Contains Diffie-Hellman groups used for the Diffie-Hellman key exchange which is critical for constructing a secure transport layer. When keys are exchanged at the beginning of an SSH session, a shared, secret value is created which cannot be determined by either party alone. This value is then used to provide host authentication.
/etc/ssh/ssh_config	The default SSH client configuration file. Note that it is overridden by **~/.ssh/config** if it exists.
/etc/ssh/sshd_config	The configuration file for the **sshd** daemon.
/etc/ssh/ssh_host_dsa_key	The DSA private key used by the **sshd** daemon.
/etc/ssh/ssh_host_dsa_key.pub	The DSA public key used by the **sshd** daemon.
/etc/ssh/ssh_host_key	The RSA private key used by the **sshd** daemon for version 1 of the SSH protocol.
/etc/ssh/ssh_host_key.pub	The RSA public key used by the **sshd** daemon for version 1 of the SSH protocol.
/etc/ssh/ssh_host_rsa_key	The RSA private key used by the **sshd** daemon for version 2 of the SSH protocol.
/etc/ssh/ssh_host_rsa_key.pub	The RSA public key used by the **sshd** for version 2 of the SSH protocol.

User-specific SSH configuration information is stored in the user's home directory within the **~/.ssh/** directory. See *Table 10.2, "User-specific configuration files"* for a description of its content.

Table 10.2. User-specific configuration files

Configuration File	Description
~/.ssh/authorized_keys	Holds a list of authorized public keys for servers. When the client connects to a server, the server authenticates the client by checking its signed public key stored within this file.
~/.ssh/id_dsa	Contains the DSA private key of the user.
~/.ssh/id_dsa.pub	The DSA public key of the user.
~/.ssh/id_rsa	The RSA private key used by **ssh** for version 2 of the SSH protocol.
~/.ssh/id_rsa.pub	The RSA public key used by **ssh** for version 2 of the SSH protocol
~/.ssh/identity	The RSA private key used by **ssh** for version 1 of the SSH protocol.
~/.ssh/identity.pub	The RSA public key used by **ssh** for version 1 of the SSH protocol.

Configuration File	Description
~/.ssh/known_hosts	Contains DSA host keys of SSH servers accessed by the user. This file is very important for ensuring that the SSH client is connecting the correct SSH server.

Refer to the **ssh_config** and **sshd_config** man pages for information concerning the various directives available in the SSH configuration files.

10.2.2. Starting an OpenSSH Server



Make sure you have relevant packages installed

To run an OpenSSH server, you must have the *openssh-server* and *openssh* packages installed. Refer to *Section 4.2.4, "Installing Packages"* for more information on how to install new packages in Fedora.

To start the **sshd** daemon, type the following at a shell prompt:

```
systemctl start sshd.service
```

To stop the running **sshd** daemon, use the following command:

```
systemctl stop sshd.service
```

If you want the daemon to start automatically at the boot time, type:

```
systemctl enable sshd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

Note that if you reinstall the system, a new set of identification keys will be created. As a result, clients who had connected to the system with any of the OpenSSH tools before the reinstall will see the following message:

```
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
Someone could be eavesdropping on you right now (man-in-the-middle attack)!
It is also possible that the RSA host key has just been changed.
```

To prevent this, you can back up the relevant files from the **/etc/ssh/** directory (see *Table 10.1, "System-wide configuration files"* for a complete list), and restore them whenever you reinstall the system.

10.2.3. Requiring SSH for Remote Connections

For SSH to be truly effective, using insecure connection protocols should be prohibited. Otherwise, a user's password may be protected using SSH for one session, only to be captured later while logging in using Telnet. Some services to disable include **telnet**, **rsh**, **rlogin**, and **vsftpd**.

To make sure these services are not running, type the following commands at a shell prompt:

```
systemctl stop telnet.service
systemctl stop rsh.service
systemctl stop rlogin.service
systemctl stop vsftpd.service
```

To disable running these services at startup, type:

```
systemctl disable telnet.service
systemctl disable rsh.service
systemctl disable rlogin.service
systemctl disable vsftpd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

10.2.4. Using a Key-Based Authentication

To improve the system security even further, you can enforce the key-based authentication by disabling the standard password authentication. To do so, open the **/etc/ssh/sshd_config** configuration file in a text editor, and change the **PasswordAuthentication** option as follows:

```
PasswordAuthentication no
```

To be able to use **ssh**, **scp**, or **sftp** to connect to the server from a client machine, generate an authorization key pair by following the steps below. Note that keys must be generated for each user separately.

Fedora 17 uses SSH Protocol 2 and RSA keys by default (see *Section 10.1.3, "Protocol Versions"* for more information).



Do not generate key pairs as root

If you complete the steps as `root`, only `root` will be able to use the keys.



Backup your ~/.ssh/ directory

If you reinstall your system and want to keep previously generated key pair, backup the **~/.ssh/** directory. After reinstalling, copy it back to your home directory. This process can be done for all users on your system, including `root`.

10.2.4.1. Generating Key Pairs

To generate an RSA key pair for version 2 of the SSH protocol, follow these steps:

1. Generate an RSA key pair by typing the following at a shell prompt:

```
~]$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/john/.ssh/id_rsa):
```

2. Press **Enter** to confirm the default location (that is, **~/.ssh/id_rsa**) for the newly created key.

3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log in to your account.

   After this, you will be presented with a message similar to this:

```
Your identification has been saved in /home/john/.ssh/id_rsa.
Your public key has been saved in /home/john/.ssh/id_rsa.pub.
The key fingerprint is:
e7:97:c7:e2:0e:f9:0e:fc:c4:d7:cb:e5:31:11:92:14 john@penguin.example.com
The key's randomart image is:
+--[ RSA 2048]----+
|             E.  |
|            . .  |
|             o . |
|              . .|
|        S .    . |
|         + o o ..|
|          * * +oo|
|           O +..=|
|           o*  o.|
+-----------------+
```

4. Change the permissions of the **~/.ssh/** directory:

```
~]$ chmod 755 ~/.ssh
```

5. Copy the content of **~/.ssh/id_rsa.pub** into the **~/.ssh/authorized_keys** on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the **~/.ssh/authorized_keys** file using the following command:

```
~]$ chmod 644 ~/.ssh/authorized_keys
```

To generate a DSA key pair for version 2 of the SSH protocol, follow these steps:

1. Generate a DSA key pair by typing the following at a shell prompt:

```
~]$ ssh-keygen -t dsa
Generating public/private dsa key pair.
```

```
Enter file in which to save the key (/home/john/.ssh/id_dsa):
```

2. Press **Enter** to confirm the default location (that is, **~/.ssh/id_dsa**) for the newly created key.

3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log in to your account.

   After this, you will be presented with a message similar to this:

```
Your identification has been saved in /home/john/.ssh/id_dsa.
Your public key has been saved in /home/john/.ssh/id_dsa.pub.
The key fingerprint is:
81:a1:91:a8:9f:e8:c5:66:0d:54:f5:90:cc:bc:cc:27 john@penguin.example.com
The key's randomart image is:
+--[ DSA 1024]----+
|   .oo*o.        |
|  ...o Bo        |
| .. . + o.       |
|.  .   E o       |
| o..o   S        |
|. o= .           |
|. +              |
| .               |
|                 |
+-----------------+
```

4. Change the permissions of the **~/.ssh/** directory:

```
~]$ chmod 775 ~/.ssh
```

5. Copy the content of **~/.ssh/id_dsa.pub** into the **~/.ssh/authorized_keys** on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the **~/.ssh/authorized_keys** file using the following command:

```
~]$ chmod 644 ~/.ssh/authorized_keys
```

To generate an RSA key pair for version 1 of the SSH protocol, follow these steps:

1. Generate an RSA key pair by typing the following at a shell prompt:

```
~]$ ssh-keygen -t rsa1
Generating public/private rsa1 key pair.
Enter file in which to save the key (/home/john/.ssh/identity):
```

2. Press **Enter** to confirm the default location (that is, **~/.ssh/identity**) for the newly created key.

3. Enter a passphrase, and confirm it by entering it again when prompted to do so. For security reasons, avoid using the same password as you use to log into your account.

   After this, you will be presented with a message similar to this:

```
Your identification has been saved in /home/john/.ssh/identity.
```

```
Your public key has been saved in /home/john/.ssh/identity.pub.
The key fingerprint is:
cb:f6:d5:cb:6e:5f:2b:28:ac:17:0c:e4:62:e4:6f:59 john@penguin.example.com
The key's randomart image is:
+--[RSA1 2048]----+
|                 |
|     . .         |
|    o o          |
|     + o E       |
|    . o S        |
|       = +   .   |
|      . = . o . .|
|       . = o o..o|
|       .o o  o=o.|
+-----------------+
```

4. Change the permissions of the **~/.ssh/** directory:

```
~]$ chmod 755 ~/.ssh
```

5. Copy the content of **~/.ssh/identity.pub** into the **~/.ssh/authorized_keys** on the machine to which you want to connect, appending it to its end if the file already exists.

6. Change the permissions of the **~/.ssh/authorized_keys** file using the following command:

```
~]$ chmod 644 ~/.ssh/authorized_keys
```

Refer to *Section 10.2.4.2, "Configuring ssh-agent"* for information on how to set up your system to remember the passphrase.



Never share your private key

The private key is for your personal use only, and it is important that you never give it to anyone.

10.2.4.2. Configuring ssh-agent

To store your passphrase so that you do not have to enter it each time you initiate a connection with a remote machine, you can use the **ssh-agent** authentication agent. To save your passphrase for a certain shell prompt, use the following command:

```
~]$ ssh-add
Enter passphrase for /home/john/.ssh/id_rsa:
```

Note that when you log out, your passphrase will be forgotten. You must execute the command each time you log in to a virtual console or a terminal window.

10.3. OpenSSH Clients



Make sure you have relevant packages installed

To connect to an OpenSSH server from a client machine, you must have the *openssh-clients* and *openssh* packages installed. Refer to *Section 4.2.4, "Installing Packages"* for more information on how to install new packages in Fedora.

10.3.1. Using the ssh Utility

ssh allows you to log in to a remote machine and execute commands there. It is a secure replacement for the **rlogin**, **rsh**, and **telnet** programs.

Similarly to **telnet**, to log in to a remote machine named `penguin.example.com`, type the following command at a shell prompt:

```
~]$ ssh penguin.example.com
```

This will log you in with the same username you are using on a local machine. If you want to specify a different one, use a command in the **ssh *username*@*hostname*** form. For example, to log in as `john`, type:

```
~]$ ssh john@penguin.example.com
```

The first time you initiate a connection, you will be presented with a message similar to this:

```
The authenticity of host 'penguin.example.com' can't be established.
RSA key fingerprint is 94:68:3a:3a:bc:f3:9a:9b:01:5d:b3:07:38:e2:11:0c.
Are you sure you want to continue connecting (yes/no)?
```

Type **yes** to confirm. You will see a notice that the server has been added to the list of known hosts, and a prompt asking for your password:

```
Warning: Permanently added 'penguin.example.com' (RSA) to the list of known hosts.
john@penguin.example.com's password:
```



Updating the host key of an SSH server

If the SSH server's host key changes, the client notifies the user that the connection cannot proceed until the server's host key is deleted from the **~/.ssh/known_hosts** file. To do so, open the file in a text editor, and remove a line containing the remote machine name at the beginning. Before doing this, however, contact the system administrator of the SSH server to verify the server is not compromised.

After entering the password, you will be provided with a shell prompt for the remote machine.

Alternatively, the **ssh** program can be used to execute a command on the remote machine without logging in to a shell prompt. The syntax for that is **ssh [*username*@]*hostname command***. For example, if you want to execute the **whoami** command on `penguin.example.com`, type:

```
~]$ ssh john@penguin.example.com whoami
john@penguin.example.com's password:
john
```

After you enter the correct password, the username will be displayed, and you will return to your local shell prompt.

10.3.2. Using the scp Utility

scp can be used to transfer files between machines over a secure, encrypted connection. In its design, it is very similar to **rcp**.

To transfer a local file to a remote system, use a command in the following form:

```
scp localfile username@hostname:remotefile
```

For example, if you want to transfer **taglist.vim** to a remote machine named penguin.example.com, type the following at a shell prompt:

```
~]$ scp taglist.vim john@penguin.example.com:.vim/plugin/taglist.vim
john@penguin.example.com's password:
taglist.vim                                   100%  144KB 144.5KB/s   00:00
```

Multiple files can be specified at once. To transfer the contents of **.vim/plugin/** to the same directory on the remote machine penguin.example.com, type the following command:

```
~]$ scp .vim/plugin/* john@penguin.example.com:.vim/plugin/
john@penguin.example.com's password:
closetag.vim                                  100%   13KB  12.6KB/s   00:00
snippetsEmu.vim                               100%   33KB  33.1KB/s   00:00
taglist.vim                                   100%  144KB 144.5KB/s   00:00
```

To transfer a remote file to the local system, use the following syntax:

```
scp username@hostname:remotefile localfile
```

For instance, to download the **.vimrc** configuration file from the remote machine, type:

```
~]$ scp john@penguin.example.com:.vimrc .vimrc
john@penguin.example.com's password:
.vimrc                                        100% 2233     2.2KB/s   00:00
```

10.3.3. Using the sftp Utility

The **sftp** utility can be used to open a secure, interactive FTP session. In its design, it is similar to **ftp** except that it uses a secure, encrypted connection.

To connect to a remote system, use a command in the following form:

```
sftp username@hostname
```

For example, to log in to a remote machine named `penguin.example.com` with `john` as a username, type:

```
~]$ sftp john@penguin.example.com
john@penguin.example.com's password:
Connected to penguin.example.com.
sftp>
```

After you enter the correct password, you will be presented with a prompt. The **sftp** utility accepts a set of commands similar to those used by **ftp** (see *Table 10.3, "A selection of available sftp commands"*).

Table 10.3. A selection of available sftp commands

Command	Description
ls [*directory*]	List the content of a remote *directory*. If none is supplied, a current working directory is used by default.
cd *directory*	Change the remote working directory to *directory*.
mkdir *directory*	Create a remote *directory*.
rmdir *path*	Remove a remote *directory*.
put *localfile* [*remotefile*]	Transfer *localfile* to a remote machine.
get *remotefile* [*localfile*]	Transfer *remotefile* from a remote machine.

For a complete list of available commands, refer to the **sftp** man page.

10.4. More Than a Secure Shell

A secure command line interface is just the beginning of the many ways SSH can be used. Given the proper amount of bandwidth, X11 sessions can be directed over an SSH channel. Or, by using TCP/IP forwarding, previously insecure port connections between systems can be mapped to specific SSH channels.

10.4.1. X11 Forwarding

To open an X11 session over an SSH connection, use a command in the following form:

```
ssh -Y username@hostname
```

For example, to log in to a remote machine named `penguin.example.com` with `john` as a username, type:

```
~]$ ssh -Y john@penguin.example.com
john@penguin.example.com's password:
```

When an X program is run from the secure shell prompt, the SSH client and server create a new secure channel, and the X program data is sent over that channel to the client machine transparently.

X11 forwarding can be very useful. For example, X11 forwarding can be used to create a secure, interactive session of the **Printer Configuration** utility. To do this, connect to the server using **ssh** and type:

```
~]$ system-config-printer &
```

The **Printer Configuration Tool** will appear, allowing the remote user to safely configure printing on the remote system.

10.4.2. Port Forwarding

SSH can secure otherwise insecure `TCP/IP` protocols via port forwarding. When using this technique, the SSH server becomes an encrypted conduit to the SSH client.

Port forwarding works by mapping a local port on the client to a remote port on the server. SSH can map any port from the server to any port on the client. Port numbers do not need to match for this technique to work.



Using reserved port numbers

Setting up port forwarding to listen on ports below 1024 requires root level access.

To create a TCP/IP port forwarding channel which listens for connections on the `localhost`, use a command in the following form:

```
ssh -L local-port:remote-hostname:remote-port username@hostname
```

For example, to check email on a server called `mail.example.com` using `POP3` through an encrypted connection, use the following command:

```
~]$ ssh -L 1100:mail.example.com:110 mail.example.com
```

Once the port forwarding channel is in place between the client machine and the mail server, direct a POP3 mail client to use port **`1100`** on the `localhost` to check for new email. Any requests sent to port **`1100`** on the client system will be directed securely to the `mail.example.com` server.

If `mail.example.com` is not running an SSH server, but another machine on the same network is, SSH can still be used to secure part of the connection. However, a slightly different command is necessary:

```
~]$ ssh -L 1100:mail.example.com:110 other.example.com
```

In this example, POP3 requests from port **`1100`** on the client machine are forwarded through the SSH connection on port **`22`** to the SSH server, `other.example.com`. Then, `other.example.com` connects to port **`110`** on `mail.example.com` to check for new email. Note that when using this technique, only the connection between the client system and `other.example.com` SSH server is secure.

Port forwarding can also be used to get information securely through network firewalls. If the firewall is configured to allow SSH traffic via its standard port (that is, port 22) but blocks access to other ports, a connection between two hosts using the blocked ports is still possible by redirecting their communication over an established SSH connection.



A connection is only as secure as a client system

Using port forwarding to forward connections in this manner allows any user on the client system to connect to that service. If the client system becomes compromised, the attacker also has access to forwarded services.

System administrators concerned about port forwarding can disable this functionality on the server by specifying a **No** parameter for the **AllowTcpForwarding** line in **/etc/ssh/sshd_config** and restarting the **sshd** service.

10.5. Additional Resources

The OpenSSH and OpenSSL projects are in constant development, and the most up-to-date information for them is available from their websites. The man pages for OpenSSH and OpenSSL tools are also good sources of detailed information.

10.5.1. Installed Documentation

man ssh
The manual page for **ssh** containing the full documentation on its usage.

man scp
The manual page for **scp** containing the full documentation on its usage.

man sftp
The manual page for **sftp** containing the full documentation on its usage.

man sshd
The manual page for **sshd** containing the full documentation on its usage.

man ssh-keygen
The manual page for **ssh-keygen** containing the full documentation on its usage.

man ssh_config
The manual page with full description of available SSH client configuration options.

man sshd_config
The manual page with full description of available SSH daemon configuration options.

10.5.2. Useful Websites

http://www.openssh.com/
The OpenSSH home page containing further documentation, frequently asked questions, links to the mailing lists, bug reports, and other useful resources.

http://www.openssl.org/
The OpenSSL home page containing further documentation, frequently asked questions, links to the mailing lists, and other useful resources.

http://www.freesshd.com/
: Another implementation of an SSH server.

Part V. Servers

This part discusses various topics related to servers such as how to set up a Web server or share files and directories over the network.

DHCP Servers

Dynamic Host Configuration Protocol (DHCP) is a network protocol that automatically assigns TCP/IP information to client machines. Each DHCP client connects to the centrally located DHCP server, which returns that client's network configuration (including the IP address, gateway, and DNS servers).

11.1. Why Use DHCP?

DHCP is useful for automatic configuration of client network interfaces. When configuring the client system, the administrator chooses DHCP instead of specifying an IP address, netmask, gateway, or DNS servers. The client retrieves this information from the DHCP server. DHCP is also useful if an administrator wants to change the IP addresses of a large number of systems. Instead of reconfiguring all the systems, he can just edit one DHCP configuration file on the server for the new set of IP addresses. If the DNS servers for an organization changes, the changes are made on the DHCP server, not on the DHCP clients. When the administrator restarts the network or reboots the clients, the changes will go into effect.

If an organization has a functional DHCP server properly connected to a network, laptops and other mobile computer users can move these devices from office to office.

11.2. Configuring a DHCP Server

The **dhcp** package contains an ISC DHCP server. First, install the package as `root`:

```
yum install dhcp
```

Installing the **dhcp** package creates a file, **/etc/dhcp/dhcpd.conf**, which is merely an empty configuration file:

```
#
# DHCP Server Configuration file.
#   see /usr/share/doc/dhcp*/dhcpd.conf.sample
#   see dhcpd.conf(5) man page
#
```

The sample configuration file can be found at **/usr/share/doc/dhcp-*version*/dhcpd.conf.sample**. You should use this file to help you configure **/etc/dhcp/dhcpd.conf**, which is explained in detail below.

DHCP also uses the file **/var/lib/dhcpd/dhcpd.leases** to store the client lease database. Refer to *Section 11.2.2, “Lease Database”* for more information.

11.2.1. Configuration File

The first step in configuring a DHCP server is to create the configuration file that stores the network information for the clients. Use this file to declare options and global options for client systems.

The configuration file can contain extra tabs or blank lines for easier formatting. Keywords are case-insensitive and lines beginning with a hash sign (#) are considered comments.

There are two types of statements in the configuration file:

- Parameters — State how to perform a task, whether to perform a task, or what network configuration options to send to the client.
- Declarations — Describe the topology of the network, describe the clients, provide addresses for the clients, or apply a group of parameters to a group of declarations.

The parameters that start with the keyword option are referred to as *options*. These options control DHCP options; whereas, parameters configure values that are not optional or control how the DHCP server behaves.

Parameters (including options) declared before a section enclosed in curly brackets ({ }) are considered global parameters. Global parameters apply to all the sections below it.



Restart the DHCP daemon for the changes to take effect

If the configuration file is changed, the changes do not take effect until the DHCP daemon is restarted. To do so, type the following at a shell prompt as `root`:

```
systemctl restart dhcpd.service
```



Use the omshell command

Instead of changing a DHCP configuration file and restarting the service each time, using the **`omshell`** command provides an interactive way to connect to, query, and change the configuration of a DHCP server. By using **`omshell`**, all changes can be made while the server is running. For more information on **`omshell`**, refer to the **`omshell`** man page.

In *Example 11.1, "Subnet declaration"*, the **`routers`**, **`subnet-mask`**, **`domain-search`**, **`domain-name-servers`**, and **`time-offset`** options are used for any **`host`** statements declared below it.

Additionally, a **`subnet`** can be declared, a **`subnet`** declaration must be included for every subnet in the network. If it is not, the DHCP server fails to start.

In this example, there are global options for every DHCP client in the subnet and a **`range`** declared. Clients are assigned an IP address within the **`range`**.

Example 11.1. Subnet declaration

```
subnet 192.168.1.0 netmask 255.255.255.0 {
        option routers                  192.168.1.254;
        option subnet-mask              255.255.255.0;
        option domain-search              "example.com";
        option domain-name-servers       192.168.1.1;
        option time-offset              -18000;     # Eastern Standard Time
 range 192.168.1.10 192.168.1.100;
```

```
}
```

To configure a DHCP server that leases a dynamic IP address to a system within a subnet, modify *Example 11.2, "Range parameter"* with your values. It declares a default lease time, maximum lease time, and network configuration values for the clients. This example assigns IP addresses in the **range** 192.168.1.10 and 192.168.1.100 to client systems.

Example 11.2. Range parameter

```
default-lease-time 600;
max-lease-time 7200;
option subnet-mask 255.255.255.0;
option broadcast-address 192.168.1.255;
option routers 192.168.1.254;
option domain-name-servers 192.168.1.1, 192.168.1.2;
option domain-search "example.com";
subnet 192.168.1.0 netmask 255.255.255.0 {
   range 192.168.1.10 192.168.1.100;
}
```

To assign an IP address to a client based on the MAC address of the network interface card, use the **hardware ethernet** parameter within a **host** declaration. As demonstrated in *Example 11.3, "Static IP address using DHCP"*, the **host apex** declaration specifies that the network interface card with the MAC address 00:A0:78:8E:9E:AA always receives the IP address 192.168.1.4.

Note that the optional parameter **host-name** can also be used to assign a host name to the client.

Example 11.3. Static IP address using DHCP

```
host apex {
   option host-name "apex.example.com";
   hardware ethernet 00:A0:78:8E:9E:AA;
   fixed-address 192.168.1.4;
}
```

All subnets that share the same physical network should be declared within a **shared-network** declaration as shown in *Example 11.4, "Shared-network declaration"*. Parameters within the **shared-network**, but outside the enclosed **subnet** declarations, are considered to be global parameters. The name of the **shared-network** must be a descriptive title for the network, such as using the title 'test-lab' to describe all the subnets in a test lab environment.

Example 11.4. Shared-network declaration

```
shared-network name {
    option domain-search             "test.redhat.com";
    option domain-name-servers      ns1.redhat.com, ns2.redhat.com;
    option routers                  192.168.0.254;
    more parameters for EXAMPLE shared-network
    subnet 192.168.1.0 netmask 255.255.252.0 {
        parameters for subnet
        range 192.168.1.1 192.168.1.254;
    }
    subnet 192.168.2.0 netmask 255.255.252.0 {
        parameters for subnet
        range 192.168.2.1 192.168.2.254;
```

```
    }
}
```

As demonstrated in *Example 11.5, "Group declaration"*, the **group** declaration is used to apply global parameters to a group of declarations. For example, shared networks, subnets, and hosts can be grouped.

Example 11.5. Group declaration

```
group {
   option routers                  192.168.1.254;
   option subnet-mask              255.255.255.0;
   option domain-search              "example.com";
   option domain-name-servers       192.168.1.1;
   option time-offset              -18000;     # Eastern Standard Time
   host apex {
      option host-name "apex.example.com";
      hardware ethernet 00:A0:78:8E:9E:AA;
      fixed-address 192.168.1.4;
   }
   host raleigh {
      option host-name "raleigh.example.com";
      hardware ethernet 00:A1:DD:74:C3:F2;
      fixed-address 192.168.1.6;
   }
}
```

Using the sample configuration file

The sample configuration file provided can be used as a starting point and custom configuration options can be added to it. To copy it to the proper location, use the following command:

```
cp /usr/share/doc/dhcp-version-number/dhcpd.conf.sample /etc/dhcp/dhcpd.conf
```

... where *version-number* is the DHCP version number.

For a complete list of option statements and what they do, refer to the **dhcp-options** man page.

11.2.2. Lease Database

On the DHCP server, the file **/var/lib/dhcpd/dhcpd.leases** stores the DHCP client lease database. Do not change this file. DHCP lease information for each recently assigned IP address is automatically stored in the lease database. The information includes the length of the lease, to whom the IP address has been assigned, the start and end dates for the lease, and the MAC address of the network interface card that was used to retrieve the lease.

All times in the lease database are in Coordinated Universal Time (UTC), not local time.

The lease database is recreated from time to time so that it is not too large. First, all known leases are saved in a temporary lease database. The **dhcpd.leases** file is renamed **dhcpd.leases~** and the temporary lease database is written to **dhcpd.leases**.

The DHCP daemon could be killed or the system could crash after the lease database has been renamed to the backup file but before the new file has been written. If this happens, the **dhcpd.leases** file does not exist, but it is required to start the service. Do not create a new lease file. If you do, all old leases are lost which causes many problems. The correct solution is to rename the **dhcpd.leases~** backup file to **dhcpd.leases** and then start the daemon.

11.2.3. Starting and Stopping the Server



Starting the DHCP server for the first time

When the DHCP server is started for the first time, it fails unless the **dhcpd.leases** file exists. Use the command **touch /var/lib/dhcpd/dhcpd.leases** to create the file if it does not exist.

If the same server is also running BIND as a DNS server, this step is not necessary, as starting the **named** service automatically checks for a **dhcpd.leases** file.

To start the DHCP service, use the following command:

```
systemctl start dhcpd.service
```

To stop the DHCP server, type:

```
systemctl stop dhcpd.service
```

By default, the DHCP service does not start at boot time. To configure the daemon to start automatically at boot time, run:

```
systemctl enable dhcpd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

If more than one network interface is attached to the system, but the DHCP server should only be started on one of the interfaces, configure the DHCP server to start only on that device. In **/etc/sysconfig/dhcpd**, add the name of the interface to the list of **DHCPDARGS**:

```
# Command line options here
DHCPDARGS=eth0
```

This is useful for a firewall machine with two network cards. One network card can be configured as a DHCP client to retrieve an IP address to the Internet. The other network card can be used as a DHCP server for the internal network behind the firewall. Specifying only the network card connected to the internal network makes the system more secure because users can not connect to the daemon via the Internet.

Other command line options that can be specified in **/etc/sysconfig/dhcpd** include:

- **-p *portnum*** — Specifies the UDP port number on which **dhcpd** should listen. The default is port 67. The DHCP server transmits responses to the DHCP clients at a port number one greater than the UDP port specified. For example, if the default port 67 is used, the server listens on port 67 for requests and responses to the client on port 68. If a port is specified here and the DHCP relay agent is used, the same port on which the DHCP relay agent should listen must be specified. Refer to *Section 11.2.4, "DHCP Relay Agent"* for details.
- **-f** — Runs the daemon as a foreground process. This is mostly used for debugging.
- **-d** — Logs the DHCP server daemon to the standard error descriptor. This is mostly used for debugging. If this is not specified, the log is written to **/var/log/messages**.
- **-cf *filename*** — Specifies the location of the configuration file. The default location is **/etc/dhcp/dhcpd.conf**.
- **-lf *filename*** — Specifies the location of the lease database file. If a lease database file already exists, it is very important that the same file be used every time the DHCP server is started. It is strongly recommended that this option only be used for debugging purposes on non-production machines. The default location is **/var/lib/dhcpd/dhcpd.leases**.
- **-q** — Do not print the entire copyright message when starting the daemon.

11.2.4. DHCP Relay Agent

The DHCP Relay Agent (**dhcrelay**) allows for the relay of DHCP and BOOTP requests from a subnet with no DHCP server on it to one or more DHCP servers on other subnets.

When a DHCP client requests information, the DHCP Relay Agent forwards the request to the list of DHCP servers specified when the DHCP Relay Agent is started. When a DHCP server returns a reply, the reply is broadcast or unicast on the network that sent the original request.

The DHCP Relay Agent listens for DHCP requests on all interfaces unless the interfaces are specified in **/etc/sysconfig/dhcrelay** with the **INTERFACES** directive.

To start the DHCP Relay Agent, use the following command:

```
systemctl start dhcrelay.service
```

11.3. Configuring a DHCP Client

To configure a DHCP client manually, modify the **/etc/sysconfig/network** file to enable networking and the configuration file for each network device in the **/etc/sysconfig/network-scripts** directory. In this directory, each device should have a configuration file named **ifcfg-eth0**, where **eth0** is the network device name.

The **/etc/sysconfig/network-scripts/ifcfg-eth0** file should contain the following lines:

```
DEVICE=eth0
BOOTPROTO=dhcp
ONBOOT=yes
```

A configuration file is needed for each device to be configured to use DHCP.

Other options for the network script includes:

- **DHCP_HOSTNAME** — Only use this option if the DHCP server requires the client to specify a hostname before receiving an IP address. (The DHCP server daemon in Fedora does not support this feature.)
- **PEERDNS=*answer*** , where ***answer*** is one of the following:
  - **yes** — Modify **/etc/resolv.conf** with information from the server. If using DHCP, then **yes** is the default.
  - **no** — Do not modify **/etc/resolv.conf**.



Advanced configurations

For advanced configurations of client DHCP options such as protocol timing, lease requirements and requests, dynamic DNS support, aliases, as well as a wide variety of values to override, prepend, or append to client-side configurations, refer to the **dhclient** and **dhclient.conf** man pages.

11.4. Configuring a Multihomed DHCP Server

A multihomed DHCP server serves multiple networks, that is, multiple subnets. The examples in these sections detail how to configure a DHCP server to serve multiple networks, select which network interfaces to listen on, and how to define network settings for systems that move networks.

Before making any changes, back up the existing **/etc/sysconfig/dhcpd** and **/etc/dhcp/dhcpd.conf** files.

The DHCP daemon listens on all network interfaces unless otherwise specified. Use the **/etc/sysconfig/dhcpd** file to specify which network interfaces the DHCP daemon listens on. The following **/etc/sysconfig/dhcpd** example specifies that the DHCP daemon listens on the **eth0** and **eth1** interfaces:

```
DHCPDARGS="eth0 eth1";
```

If a system has three network interfaces cards -- **eth0**, **eth1**, and **eth2** -- and it is only desired that the DHCP daemon listens on **eth0**, then only specify **eth0** in **/etc/sysconfig/dhcpd**:

```
DHCPDARGS="eth0";
```

The following is a basic **/etc/dhcp/dhcpd.conf** file, for a server that has two network interfaces, **eth0** in a 10.0.0.0/24 network, and **eth1** in a 172.16.0.0/24 network. Multiple **subnet** declarations allow different settings to be defined for multiple networks:

```
default-lease-time 600;
max-lease-time 7200;
subnet 10.0.0.0 netmask 255.255.255.0 {
 option subnet-mask 255.255.255.0;
 option routers 10.0.0.1;
 range 10.0.0.5 10.0.0.15;
}
subnet 172.16.0.0 netmask 255.255.255.0 {
 option subnet-mask 255.255.255.0;
```

```
 option routers 172.16.0.1;
 range 172.16.0.5 172.16.0.15;
}
```

subnet *10.0.0.0* netmask *255.255.255.0*;

A **subnet** declaration is required for every network your DHCP server is serving. Multiple subnets require multiple **subnet** declarations. If the DHCP server does not have a network interface in a range of a **subnet** declaration, the DHCP server does not serve that network.

If there is only one **subnet** declaration, and no network interfaces are in the range of that subnet, the DHCP daemon fails to start, and an error such as the following is logged to **/var/log/messages**:

```
dhcpd: No subnet declaration for eth0 (0.0.0.0).
dhcpd: ** Ignoring requests on eth0.  If this is not what
dhcpd:    you want, please write a subnet declaration
dhcpd:    in your dhcpd.conf file for the network segment
dhcpd:    to which interface eth1 is attached. **
dhcpd:
dhcpd:
dhcpd: Not configured to listen on any interfaces!
```

option subnet-mask *255.255.255.0*;

The **option subnet-mask** option defines a subnet mask, and overrides the **netmask** value in the **subnet** declaration. In simple cases, the subnet and netmask values are the same.

option routers *10.0.0.1*;

The **option routers** option defines the default gateway for the subnet. This is required for systems to reach internal networks on a different subnet, as well as external networks.

range *10.0.0.5 10.0.0.15*;

The **range** option specifies the pool of available IP addresses. Systems are assigned an address from the range of specified IP addresses.

For further information, refer to the **dhcpd.conf(5)** man page.



Do not use alias interfaces

Alias interfaces are not supported by DHCP. If an alias interface is the only interface, in the only subnet specified in **/etc/dhcp/dhcpd.conf**, the DHCP daemon fails to start.

11.4.1. Host Configuration

Before making any changes, back up the existing **/etc/sysconfig/dhcpd** and **/etc/dhcp/dhcpd.conf** files.

Configuring a single system for multiple networks

The following **/etc/dhcp/dhcpd.conf** example creates two subnets, and configures an IP address for the same system, depending on which network it connects to:

```
default-lease-time 600;
```

```
max-lease-time 7200;
subnet 10.0.0.0 netmask 255.255.255.0 {
 option subnet-mask 255.255.255.0;
 option routers 10.0.0.1;
 range 10.0.0.5 10.0.0.15;
}
subnet 172.16.0.0 netmask 255.255.255.0 {
 option subnet-mask 255.255.255.0;
 option routers 172.16.0.1;
 range 172.16.0.5 172.16.0.15;
}
host example0 {
 hardware ethernet 00:1A:6B:6A:2E:0B;
 fixed-address 10.0.0.20;
}
host example1 {
 hardware ethernet 00:1A:6B:6A:2E:0B;
 fixed-address 172.16.0.20;
}
```

`host` *`example0`*
: The **`host`** declaration defines specific parameters for a single system, such as an IP address. To configure specific parameters for multiple hosts, use multiple **`host`** declarations.

  Most DHCP clients ignore the name in **`host`** declarations, and as such, this name can anything, as long as it is unique to other **`host`** declarations. To configure the same system for multiple networks, use a different name for each **`host`** declaration, otherwise the DHCP daemon fails to start. Systems are identified by the **`hardware ethernet`** option, not the name in the **`host`** declaration.

`hardware ethernet` *`00:1A:6B:6A:2E:0B`*`;`
: The **`hardware ethernet`** option identifies the system. To find this address, run the **`ip link`** command.

`fixed-address` *`10.0.0.20`*`;`
: The **`fixed-address`** option assigns a valid IP address to the system specified by the **`hardware ethernet`** option. This address must be outside the IP address pool specified with the **`range`** option.

If **`option`** statements do not end with a semicolon, the DHCP daemon fails to start, and an error such as the following is logged to **`/var/log/messages`**:

```
/etc/dhcp/dhcpd.conf line 20: semicolon expected.
dhcpd: }
dhcpd: ^
dhcpd: /etc/dhcp/dhcpd.conf line 38: unexpected end of file
dhcpd:
dhcpd: ^
dhcpd: Configuration file errors encountered -- exiting
```

Configuring systems with multiple network interfaces

The following **`host`** declarations configure a single system, that has multiple network interfaces, so that each interface receives the same IP address. This configuration will not work if both network interfaces are connected to the same network at the same time:

```
host interface0 {
 hardware ethernet 00:1a:6b:6a:2e:0b;
 fixed-address 10.0.0.18;
```

```
}
host interface1 {
 hardware ethernet 00:1A:6B:6A:27:3A;
 fixed-address 10.0.0.18;
}
```

For this example, **interface0** is the first network interface, and **interface1** is the second interface. The different **hardware ethernet** options identify each interface.

If such a system connects to another network, add more **host** declarations, remembering to:

- assign a valid **fixed-address** for the network the host is connecting to.
- make the name in the **host** declaration unique.

When a name given in a **host** declaration is not unique, the DHCP daemon fails to start, and an error such as the following is logged to **/var/log/messages**:

```
dhcpd: /etc/dhcp/dhcpd.conf line 31: host interface0: already exists
dhcpd: }
dhcpd: ^
dhcpd: Configuration file errors encountered -- exiting
```

This error was caused by having multiple **host interface0** declarations defined in **/etc/dhcp/dhcpd.conf**.

11.5. DHCP for IPv6 (DHCPv6)

The ISC DHCP includes support for IPv6 (DHCPv6) since the 4.x release with a DHCPv6 server, client and relay agent functionality. The server, client and relay agents support both IPv4 and IPv6. However, the client and the server can only manage one protocol at a time — for dual support they must be started separately for IPv4 and IPv6.

The DHCPv6 server configuration file can be found at **/etc/dhcp/dhcpd6.conf**.

The sample server configuration file can be found at **/usr/share/doc/dhcp-version/dhcpd6.conf.sample**.

To start the DHCPv6 service, use the following command:

```
systemctl start dhcpd6.service
```

A simple DHCPv6 server configuration file can look like this:

```
subnet6 2001:db8:0:1::/64 {
        range6 2001:db8:0:1::129 2001:db8:0:1::254;
        option dhcp6.name-servers fec0:0:0:1::1;
        option dhcp6.domain-search "domain.example";
}
```

11.6. Additional Resources

For additional information, refer to *The DHCP Handbook; Ralph Droms and Ted Lemon; 2003* or the following resources.

11.6.1. Installed Documentation

- **dhcpd** man page — Describes how the DHCP daemon works.
- **dhcpd.conf** man page — Explains how to configure the DHCP configuration file; includes some examples.
- **dhcpd.leases** man page — Describes a persistent database of leases.
- **dhcp-options** man page — Explains the syntax for declaring DHCP options in **dhcpd.conf**; includes some examples.
- **dhcrelay** man page — Explains the DHCP Relay Agent and its configuration options.
- **/usr/share/doc/dhcp-*version*/** — Contains sample files, README files, and release notes for current versions of the DHCP service.

DNS Servers

DNS (Domain Name System), also known as a *nameserver*, is a network system that associates hostnames with their respective IP addresses. For users, this has the advantage that they can refer to machines on the network by names that are usually easier to remember than the numerical network addresses. For system administrators, using the nameserver allows them to change the IP address for a host without ever affecting the name-based queries, or to decide which machines handle these queries.

12.1. Introduction to DNS

DNS is usually implemented using one or more centralized servers that are authoritative for certain domains. When a client host requests information from a nameserver, it usually connects to port 53. The nameserver then attempts to resolve the name requested. If it does not have an authoritative answer, or does not already have the answer cached from an earlier query, it queries other nameservers, called *root nameservers*, to determine which nameservers are authoritative for the name in question, and then queries them to get the requested name.

12.1.1. Nameserver Zones

In a DNS server such as BIND, all information is stored in basic data elements called *resource records* (RR). The resource record is usually a *fully qualified domain name* (FQDN) of a host, and is broken down into multiple sections organized into a tree-like hierarchy. This hierarchy consists of a main trunk, primary branches, secondary branches, and so on. The following is an example of a resource record:

```
bob.sales.example.com
```

Each level of the hierarchy is divided by a period (that is, **.**). In the example above, **com** defines the *top-level domain*, **example** its subdomain, and **sales** the subdomain of **example**. In this case, **bob** identifies a resource record that is part of the `sales.example.com` domain. With the exception of the part furthest to the left (that is, **bob**), each of these sections is called a *zone* and defines a specific *namespace*.

Zones are defined on authoritative nameservers through the use of *zone files*, which contain definitions of the resource records in each zone. Zone files are stored on *primary nameservers* (also called *master nameservers*), where changes are made to the files, and *secondary nameservers* (also called *slave nameservers*), which receive zone definitions from the primary nameservers. Both primary and secondary nameservers are authoritative for the zone and look the same to clients. Depending on the configuration, any nameserver can also serve as a primary or secondary server for multiple zones at the same time.

12.1.2. Nameserver Types

There are two nameserver configuration types:

authoritative
: Authoritative nameservers answer to resource records that are part of their zones only. This category includes both primary (master) and secondary (slave) nameservers.

recursive
Recursive nameservers offer resolution services, but they are not authoritative for any zone. Answers for all resolutions are cached in a memory for a fixed period of time, which is specified by the retrieved resource record.

Although a nameserver can be both authoritative and recursive at the same time, it is recommended not to combine the configuration types. To be able to perform their work, authoritative servers should be available to all clients all the time. On the other hand, since the recursive lookup takes far more time than authoritative responses, recursive servers should be available to a restricted number of clients only, otherwise they are prone to distributed denial of service (DDoS) attacks.

12.1.3. BIND as a Nameserver

BIND consists of a set of DNS-related programs. It contains a monolithic nameserver called `named`, an administration utility called **`rndc`**, and a debugging tool called **`dig`**. Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

12.2. BIND

This chapter covers `BIND` (Berkeley Internet Name Domain), the DNS server included in Fedora. It focuses on the structure of its configuration files, and describes how to administer it both locally and remotely.

12.2.1. Configuring the named Service

When the `named` service is started, it reads the configuration from the files as described in *Table 12.1, "The named service configuration files"*.

Table 12.1. The named service configuration files

Path	Description
`/etc/named.conf`	The main configuration file.
`/etc/named/`	An auxiliary directory for configuration files that are included in the main configuration file.

The configuration file consists of a collection of statements with nested options surrounded by opening and closing curly brackets (that is, **`{`** and **`}`**). Note that when editing the file, you have to be careful not to make any syntax error, otherwise the `named` service will not start. A typical **`/etc/named.conf`** file is organized as follows:

```
statement-1 ["statement-1-name"] [statement-1-class] {
  option-1;
  option-2;
  option-N;
};
statement-2 ["statement-2-name"] [statement-2-class] {
  option-1;
  option-2;
  option-N;
};
statement-N ["statement-N-name"] [statement-N-class] {
  option-1;
```

```
  option-2;
  option-N;
};
```



Running BIND in a chroot environment

If you have installed the *bind-chroot* package, the BIND service will run in the **/var/named/chroot** environment. In that case, the initialization script will mount the above configuration files using the **mount --bind** command, so that you can manage the configuration outside this environment.

12.2.1.1. Common Statement Types

The following types of statements are commonly used in **/etc/named.conf**:

acl

The **acl** (Access Control List) statement allows you to define groups of hosts, so that they can be permitted or denied access to the nameserver. It takes the following form:

```
acl acl-name {
  match-element;
  ...
};
```

The *acl-name* statement name is the name of the access control list, and the *match-element* option is usually an individual IP address (such as **10.0.1.1**) or a CIDR network notation (for example, **10.0.1.0/24**). For a list of already defined keywords, see *Table 12.2, "Predefined access control lists"*.

Table 12.2. Predefined access control lists

Keyword	Description
any	Matches every IP address.
localhost	Matches any IP address that is in use by the local system.
localnets	Matches any IP address on any network to which the local system is connected.
none	Does not match any IP address.

The **acl** statement can be especially useful with conjunction with other statements such as **options**. *Example 12.1, "Using acl in conjunction with options"* defines two access control lists, **black-hats** and **red-hats**, and adds **black-hats** on the blacklist while granting **red-hats** a normal access.

Example 12.1. Using acl in conjunction with options

```
acl black-hats {
  10.0.2.0/24;
  192.168.0.0/24;
  1234:5678::9abc/24;
};
acl red-hats {
  10.0.1.0/24;
};
options {
```

```
  blackhole { black-hats; };
  allow-query { red-hats; };
  allow-query-cache { red-hats; };
};
```

include

The **include** statement allows you to include files in the **/etc/named.conf**, so that potentially sensitive data can be placed in a separate file with restricted permissions. It takes the following form:

```
include "file-name"
```

The *file-name* statement name is an absolute path to a file.

Example 12.2. Including a file to /etc/named.conf

```
include "/etc/named.rfc1912.zones";
```

options

The **options** statement allows you to define global server configuration options as well as to set defaults for other statements. It can be used to specify the location of the named working directory, the types of queries allowed, and much more. It takes the following form:

```
options {
  option;
  ...
};
```

For a list of frequently used *option* directives, see *Table 12.3, "Commonly used options"* below.

Table 12.3. Commonly used options

Option	Description
allow-query	Specifies which hosts are allowed to query the nameserver for authoritative resource records. It accepts an access control lists, a collection of IP addresses, or networks in the CIDR notation. All hosts are allowed by default.
allow-query-cache	Specifies which hosts are allowed to query the nameserver for non-authoritative data such as recursive queries. Only **localhost** and **localnets** are allowed by default.
blackhole	Specifies which hosts are *not* allowed to query the nameserver. This option should be used when particular host or network floods the server with requests. The default option is **none**.
directory	Specifies a working directory for the named service. The default option is **/var/named/**.
dnssec-enable	Specifies whether to return DNSSEC related resource records. The default option is **yes**.
dnssec-validation	Specifies whether to prove that resource records are authentic via DNSSEC. The default option is **yes**.
forwarders	Specifies a list of valid IP addresses for nameservers to which the requests should be forwarded for resolution.

Option	Description
forward	Specifies the behavior of the **forwarders** directive. It accepts the following options: • **first** — The server will query the nameservers listed in the **forwarders** directive before attempting to resolve the name on its own. • **only** — When unable to query the nameservers listed in the **forwarders** directive, the server will not attempt to resolve the name on its own.
listen-on	Specifies the IPv4 network interface on which to listen for queries. On a DNS server that also acts as a gateway, you can use this option to answer queries originating from a single network only. All IPv4 interfaces are used by default.
listen-on-v6	Specifies the IPv6 network interface on which to listen for queries. On a DNS server that also acts as a gateway, you can use this option to answer queries originating from a single network only. All IPv6 interfaces are used by default.
max-cache-size	Specifies the maximum amount of memory to be used for server caches. When the limit is reached, the server causes records to expire prematurely so that the limit is not exceeded. In a server with multiple views, the limit applies separately to the cache of each view. The default option is **32M**.
notify	Specifies whether to notify the secondary nameservers when a zone is updated. It accepts the following options: • **yes** — The server will notify all secondary nameservers. • **no** — The server will *not* notify any secondary nameserver. • **master-only** — The server will notify primary server for the zone only. • **explicit** — The server will notify only the secondary servers that are specified in the **also-notify** list within a zone statement.
pid-file	Specifies the location of the process ID file created by the `named` service.
recursion	Specifies whether to act as a recursive server. The default option is **yes**.
statistics-file	Specifies an alternate location for statistics files. The **/var/named/named.stats** file is used by default.



Restrict recursive servers to selected clients only

To prevent distributed denial of service (DDoS) attacks, it is recommended that you use the **allow-query-cache** option to restrict recursive DNS services for a particular subset of clients only.

Refer to the *BIND 9 Administrator Reference Manual* referenced in *Section 12.2.7.1, "Installed Documentation"*, and the **named.conf** manual page for a complete list of available options.

Example 12.3. Using the options statement

```
options {
  allow-query       { localhost; };
  listen-on port    53 { 127.0.0.1; };
  listen-on-v6 port 53 { ::1; };
  max-cache-size    256M;
  directory         "/var/named";
  statistics-file   "/var/named/data/named_stats.txt";

  recursion         yes;
  dnssec-enable     yes;
  dnssec-validation yes;
};
```

zone

The **zone** statement allows you to define the characteristics of a zone, such as the location of its configuration file and zone-specific options, and can be used to override the global **options** statements. It takes the following form:

```
zone zone-name [zone-class] {
  option;
  ...
};
```

The *zone-name* attribute is the name of the zone, *zone-class* is the optional class of the zone, and *option* is a **zone** statement option as described in *Table 12.4, "Commonly used options"*.

The *zone-name* attribute is particularly important, as it is the default value assigned for the **$ORIGIN** directive used within the corresponding zone file located in the **/var/named/** directory. The named daemon appends the name of the zone to any non-fully qualified domain name listed in the zone file. For example, if a **zone** statement defines the namespace for **example.com**, use **example.com** as the *zone-name* so that it is placed at the end of hostnames within the **example.com** zone file.

For more information about zone files, refer to *Section 12.2.2, "Editing Zone Files"*.

Table 12.4. Commonly used options

Option	Description
allow-query	Specifies which clients are allowed to request information about this zone. This option overrides global **allow-query** option. All query requests are allowed by default.
allow-transfer	Specifies which secondary servers are allowed to request a transfer of the zone's information. All transfer requests are allowed by default.
allow-update	Specifies which hosts are allowed to dynamically update information in their zone. The default option is to deny all dynamic update requests. Note that you should be careful when allowing hosts to update information about their zone. Do not set IP addresses in this option unless the server is in the trusted network. Instead, use TSIG key as described in *Section 12.2.5.3, "Transaction SIGnatures (TSIG)"*.

Option	Description
file	Specifies the name of the file in the named working directory that contains the zone's configuration data.
masters	Specifies from which IP addresses to request authoritative zone information. This option is used only if the zone is defined as **type slave**.
notify	Specifies whether to notify the secondary nameservers when a zone is updated. It accepts the following options: • **yes** — The server will notify all secondary nameservers. • **no** — The server will *not* notify any secondary nameserver. • **master-only** — The server will notify primary server for the zone only. • **explicit** — The server will notify only the secondary servers that are specified in the **also-notify** list within a zone statement.
type	Specifies the zone type. It accepts the following options: • **delegation-only** — Enforces the delegation status of infrastructure zones such as COM, NET, or ORG. Any answer that is received without an explicit or implicit delegation is treated as **NXDOMAIN**. This option is only applicable in TLDs or root zone files used in recursive or caching implementations. • **forward** — Forwards all requests for information about this zone to other nameservers. • **hint** — A special type of zone used to point to the root nameservers which resolve queries when a zone is not otherwise known. No configuration beyond the default is necessary with a **hint** zone. • **master** — Designates the nameserver as authoritative for this zone. A zone should be set as the **master** if the zone's configuration files reside on the system. • **slave** — Designates the nameserver as a slave server for this zone. Master server is specified in **masters** directive.

Most changes to the **/etc/named.conf** file of a primary or secondary nameserver involve adding, modifying, or deleting **zone** statements, and only a small subset of **zone** statement options is usually needed for a nameserver to work efficiently.

In *Example 12.4, "A zone statement for a primary nameserver"*, the zone is identified as **example.com**, the type is set to **master**, and the named service is instructed to read the **/var/named/example.com.zone** file. It also allows only a secondary nameserver (**192.168.0.2**) to transfer the zone.

Example 12.4. A zone statement for a primary nameserver

```
zone "example.com" IN {
  type master;
  file "example.com.zone";
  allow-transfer { 192.168.0.2; };
```

```
};
```

A secondary server's **zone** statement is slightly different. The type is set to **slave**, and the **masters** directive is telling named the IP address of the master server.

In *Example 12.5, "A zone statement for a secondary nameserver"*, the named service is configured to query the primary server at the **192.168.0.1** IP address for information about the **example.com** zone. The received information is then saved to the **/var/named/slaves/example.com.zone** file. Note that you have to put all slave zones to **/var/named/slaves** directory, otherwise the service will fail to transfer the zone.

Example 12.5. A zone statement for a secondary nameserver

```
zone "example.com" {
  type slave;
  file "slaves/example.com.zone";
  masters { 192.168.0.1; };
};
```

12.2.1.2. Other Statement Types

The following types of statements are less commonly used in **/etc/named.conf**:

controls
The **controls** statement allows you to configure various security requirements necessary to use the **rndc** command to administer the named service.

Refer to *Section 12.2.3, "Using the rndc Utility"* for more information on the **rndc** utility and its usage.

key
The **key** statement allows you to define a particular key by name. Keys are used to authenticate various actions, such as secure updates or the use of the **rndc** command. Two options are used with **key**:

- **algorithm *algorithm-name*** — The type of algorithm to be used (for example, **hmac-md5**).
- **secret "*key-value*"** — The encrypted key.

Refer to *Section 12.2.3, "Using the rndc Utility"* for more information on the **rndc** utility and its usage.

logging
The **logging** statement allows you to use multiple types of logs, so called *channels*. By using the **channel** option within the statement, you can construct a customized type of log with its own file name (**file**), size limit (**size**), versioning (**version**), and level of importance (**severity**). Once a customized channel is defined, a **category** option is used to categorize the channel and begin logging when the named service is restarted.

By default, named sends standard messages to the rsyslog daemon, which places them in **/var/log/messages**. Several standard channels are built into BIND with various severity levels, such as **default_syslog** (which handles informational logging messages) and **default_debug** (which specifically handles debugging messages). A default category, called **default**, uses the built-in channels to do normal logging without any special configuration.

Customizing the logging process can be a very detailed process and is beyond the scope of this chapter. For information on creating custom BIND logs, refer to the *BIND 9 Administrator Reference Manual* referenced in *Section 12.2.7.1, "Installed Documentation"*.

server
The **server** statement allows you to specify options that affect how the named service should respond to remote nameservers, especially with regard to notifications and zone transfers.

The **transfer-format** option controls the number of resource records that are sent with each message. It can be either **one-answer** (only one resource record), or **many-answers** (multiple resource records). Note that while the **many-answers** option is more efficient, it is not supported by older versions of BIND.

trusted-keys
The **trusted-keys** statement allows you to specify assorted public keys used for secure DNS (DNSSEC). Refer to *Section 12.2.5.4, "DNS Security Extensions (DNSSEC)"* for more information on this topic.

view
The **view** statement allows you to create special views depending upon which network the host querying the nameserver is on. This allows some hosts to receive one answer regarding a zone while other hosts receive totally different information. Alternatively, certain zones may only be made available to particular trusted hosts while non-trusted hosts can only make queries for other zones.

Multiple views can be used as long as their names are unique. The **match-clients** option allows you to specify the IP addresses that apply to a particular view. If the **options** statement is used within a view, it overrides the already configured global options. Finally, most **view** statements contain multiple **zone** statements that apply to the **match-clients** list.

Note that the order in which the **view** statements are listed is important, as the first statement that matches a particular client's IP address is used. For more information on this topic, refer to *Section 12.2.5.1, "Multiple Views"*.

12.2.1.3. Comment Tags

Additionally to statements, the **/etc/named.conf** file can also contain comments. Comments are ignored by the named service, but can prove useful when providing additional information to a user. The following are valid comment tags:

//
Any text after the **//** characters to the end of the line is considered a comment. For example:

```
notify yes;  // notify all secondary nameservers
```

#
Any text after the # character to the end of the line is considered a comment. For example:

```
notify yes;  # notify all secondary nameservers
```

/* and ***/**
Any block of text enclosed in **/*** and ***/** is considered a comment. For example:

```
notify yes;  /* notify all secondary nameservers */
```

12.2.2. Editing Zone Files

As outlined in *Section 12.1.1, "Nameserver Zones"*, zone files contain information about a namespace. They are stored in the `named` working directory located in **`/var/named/`** by default, and each zone file is named according to the **`file`** option in the **`zone`** statement, usually in a way that relates to the domain in question and identifies the file as containing zone data, such as **`example.com.zone`**.

Table 12.5. The named service zone files

Path	Description
`/var/named/`	The working directory for the `named` service. The nameserver is *not* allowed to write to this directory.
`/var/named/slaves/`	The directory for secondary zones. This directory is writable by the `named` service.
`/var/named/dynamic/`	The directory for other files, such as dynamic DNS (DDNS) zones or managed DNSSEC keys. This directory is writable by the `named` service.
`/var/named/data/`	The directory for various statistics and debugging files. This directory is writable by the `named` service.

A zone file consists of directives and resource records. Directives tell the nameserver to perform tasks or apply special settings to the zone, resource records define the parameters of the zone and assign identities to individual hosts. While the directives are optional, the resource records are required in order to provide name service to a zone.

All directives and resource records should be entered on individual lines.

12.2.2.1. Common Directives

Directives begin with the dollar sign character (that is, **$**) followed by the name of the directive, and usually appear at the top of the file. The following directives are commonly used in zone files:

`$INCLUDE`

The **`$INCLUDE`** directive allows you to include another file at the place where it appears, so that other zone settings can be stored in a separate zone file.

Example 12.6. Using the $INCLUDE directive

```
$INCLUDE /var/named/penguin.example.com
```

`$ORIGIN`

The **`$ORIGIN`** directive allows you to append the domain name to unqualified records, such as those with the hostname only. Note that the use of this directive is not necessary if the zone is specified in **`/etc/named.conf`**, since the zone name is used by default.

In *Example 12.7, "Using the $ORIGIN directive"*, any names used in resource records that do not end in a trailing period (that is, the **`.`** character) are appended with **`example.com`**.

Example 12.7. Using the $ORIGIN directive

```
$ORIGIN example.com.
```

$TTL

The **$TTL** directive allows you to set the default *Time to Live* (TTL) value for the zone, that is, how long is a zone record valid. Each resource record can contain its own TTL value, which overrides this directive.

Increasing this value allows remote nameservers to cache the zone information for a longer period of time, reducing the number of queries for the zone and lengthening the amount of time required to proliferate resource record changes.

Example 12.8. Using the $TTL directive

```
$TTL 1D
```

12.2.2.2. Common Resource Records

The following resource records are commonly used in zone files:

A

The *Address* record specifies an IP address to be assigned to a name. It takes the following form:

```
hostname IN A IP-address
```

If the *hostname* value is omitted, the record will point to the last specified *hostname*.

In *Example 12.9, "Using the A resource record"*, the requests for `server1.example.com` are pointed to **10.0.1.3** or **10.0.1.5**.

Example 12.9. Using the A resource record

```
server1  IN  A  10.0.1.3
         IN  A  10.0.1.5
```

CNAME

The *Canonical Name* record maps one name to another. Because of this, this type of record is sometimes referred to as an *alias record*. It takes the following form:

```
alias-name IN CNAME real-name
```

CNAME records are most commonly used to point to services that use a common naming scheme, such as **www** for Web servers. However, there are multiple restrictions for their usage:

- CNAME records should not point to other CNAME records. This is mainly to avoid possible infinite loops.
- CNAME records should not contain other resource record types (such as A, NS, MX, etc.). The only exception are DNSSEC related records (that is, RRSIG, NSEC, etc.) when the zone is signed.

- Other resource record that point to the fully qualified domain name (FQDN) of a host (that is, NS, MX, PTR) should not point to a CNAME record.

In *Example 12.10, "Using the CNAME resource record"*, the **A** record binds a hostname to an IP address, while the **CNAME** record points the commonly used **www** hostname to it.

Example 12.10. Using the CNAME resource record

```
server1  IN  A      10.0.1.5
www      IN  CNAME  server1
```

MX

The *Mail Exchange* record specifies where the mail sent to a particular namespace controlled by this zone should go. It takes the following form:

```
IN MX preference-value email-server-name
```

The *email-server-name* is a fully qualified domain name (FQDN). The *preference-value* allows numerical ranking of the email servers for a namespace, giving preference to some email systems over others. The **MX** resource record with the lowest *preference-value* is preferred over the others. However, multiple email servers can possess the same value to distribute email traffic evenly among them.

In *Example 12.11, "Using the MX resource record"*, the first `mail.example.com` email server is preferred to the `mail2.example.com` email server when receiving email destined for the `example.com` domain.

Example 12.11. Using the MX resource record

```
example.com.  IN  MX  10  mail.example.com.
              IN  MX  20  mail2.example.com.
```

NS

The *Nameserver* record announces authoritative nameservers for a particular zone. It takes the following form:

```
IN NS nameserver-name
```

The *nameserver-name* should be a fully qualified domain name (FQDN). Note that when two nameservers are listed as authoritative for the domain, it is not important whether these nameservers are secondary nameservers, or if one of them is a primary server. They are both still considered authoritative.

Example 12.12. Using the NS resource record

```
IN  NS  dns1.example.com.
IN  NS  dns2.example.com.
```

PTR

The *Pointer* record points to another part of the namespace. It takes the following form:

```
last-IP-digit IN PTR FQDN-of-system
```

The *last-IP-digit* directive is the last number in an IP address, and the *FQDN-of-system* is a fully qualified domain name (FQDN).

PTR records are primarily used for reverse name resolution, as they point IP addresses back to a particular name. Refer to *Section 12.2.2.4.2, "A Reverse Name Resolution Zone File"* for more examples of **PTR** records in use.

SOA

The *Start of Authority* record announces important authoritative information about a namespace to the nameserver. Located after the directives, it is the first resource record in a zone file. It takes the following form:

```
@  IN  SOA  primary-name-server hostmaster-email (
       serial-number
       time-to-refresh
       time-to-retry
       time-to-expire
       minimum-TTL )
```

The directives are as follows:

- The @ symbol places the **$ORIGIN** directive (or the zone's name if the **$ORIGIN** directive is not set) as the namespace being defined by this **SOA** resource record.
- The *primary-name-server* directive is the hostname of the primary nameserver that is authoritative for this domain.
- The *hostmaster-email* directive is the email of the person to contact about the namespace.
- The *serial-number* directive is a numerical value incremented every time the zone file is altered to indicate it is time for the named service to reload the zone.
- The *time-to-refresh* directive is the numerical value secondary nameservers use to determine how long to wait before asking the primary nameserver if any changes have been made to the zone.
- The *time-to-retry* directive is a numerical value used by secondary nameservers to determine the length of time to wait before issuing a refresh request in the event that the primary nameserver is not answering. If the primary server has not replied to a refresh request before the amount of time specified in the *time-to-expire* directive elapses, the secondary servers stop responding as an authority for requests concerning that namespace.
- In BIND 4 and 8, the *minimum-TTL* directive is the amount of time other nameservers cache the zone's information. In BIND 9, it defines how long negative answers are cached for. Caching of negative answers can be set to a maximum of 3 hours (that is, **3H**).

When configuring BIND, all times are specified in seconds. However, it is possible to use abbreviations when specifying units of time other than seconds, such as minutes (**M**), hours (**H**), days (**D**), and weeks (**W**). *Table 12.6, "Seconds compared to other time units"* shows an amount of time in seconds and the equivalent time in another format.

Table 12.6. Seconds compared to other time units

Seconds	Other Time Units
60	**1M**

Seconds	Other Time Units
1800	**30M**
3600	**1H**
10800	**3H**
21600	**6H**
43200	**12H**
86400	**1D**
259200	**3D**
604800	**1W**
31536000	**365D**

Example 12.13. Using the SOA resource record

```
@  IN  SOA  dns1.example.com.  hostmaster.example.com. (
       2001062501  ; serial
       21600       ; refresh after 6 hours
       3600        ; retry after 1 hour
       604800      ; expire after 1 week
       86400 )     ; minimum TTL of 1 day
```

12.2.2.3. Comment Tags

Additionally to resource records and directives, a zone file can also contain comments. Comments are ignored by the named service, but can prove useful when providing additional information to the user. Any text after the semicolon character (that is, **;**) to the end of the line is considered a comment. For example:

```
604800  ; expire after 1 week
```

12.2.2.4. Example Usage

The following examples show the basic usage of zone files.

12.2.2.4.1. A Simple Zone File

Example 12.14, "A simple zone file" demonstrates the use of standard directives and **SOA** values.

Example 12.14. A simple zone file

```
$ORIGIN example.com.
$TTL 86400
@         IN  SOA  dns1.example.com.  hostmaster.example.com. (
              2001062501  ; serial
              21600       ; refresh after 6 hours
              3600        ; retry after 1 hour
              604800      ; expire after 1 week
              86400 )     ; minimum TTL of 1 day
;
;
          IN  NS     dns1.example.com.
```

```
          IN  NS     dns2.example.com.
dns1      IN  A      10.0.1.1
          IN  AAAA   aaaa:bbbb::1
dns2      IN  A      10.0.1.2
          IN  AAAA   aaaa:bbbb::2
;
;
@         IN  MX     10  mail.example.com.
          IN  MX     20  mail2.example.com.
mail      IN  A      10.0.1.5
          IN  AAAA   aaaa:bbbb::5
mail2     IN  A      10.0.1.6
          IN  AAAA   aaaa:bbbb::6
;
;
; This sample zone file illustrates sharing the same IP addresses
; for multiple services:
;
services  IN  A      10.0.1.10
          IN  AAAA   aaaa:bbbb::10
          IN  A      10.0.1.11
          IN  AAAA   aaaa:bbbb::11

ftp       IN  CNAME  services.example.com.
www       IN  CNAME  services.example.com.
;
;
```

In this example, the authoritative nameservers are set as `dns1.example.com` and `dns2.example.com`, and are tied to the `10.0.1.1` and `10.0.1.2` IP addresses respectively using the **A** record.

The email servers configured with the **MX** records point to `mail` and `mail2` via **A** records. Since these names do not end in a trailing period (that is, the `.` character), the **$ORIGIN** domain is placed after them, expanding them to `mail.example.com` and `mail2.example.com`.

Services available at the standard names, such as `www.example.com` (WWW), are pointed at the appropriate servers using the **CNAME** record.

This zone file would be called into service with a **zone** statement in the **/etc/named.conf** similar to the following:

```
zone "example.com" IN {
  type master;
  file "example.com.zone";
  allow-update { none; };
};
```

12.2.2.4.2. A Reverse Name Resolution Zone File

A reverse name resolution zone file is used to translate an IP address in a particular namespace into an fully qualified domain name (FQDN). It looks very similar to a standard zone file, except that the **PTR** resource records are used to link the IP addresses to a fully qualified domain name as shown in *Example 12.15, "A reverse name resolution zone file"*.

Example 12.15. A reverse name resolution zone file

```
$ORIGIN 1.0.10.in-addr.arpa.
```

```
$TTL 86400
@  IN  SOA  dns1.example.com.  hostmaster.example.com. (
       2001062501  ; serial
       21600       ; refresh after 6 hours
       3600        ; retry after 1 hour
       604800      ; expire after 1 week
       86400 )     ; minimum TTL of 1 day
;
@  IN  NS   dns1.example.com.
;
1  IN  PTR  dns1.example.com.
2  IN  PTR  dns2.example.com.
;
5  IN  PTR  server1.example.com.
6  IN  PTR  server2.example.com.
;
3  IN  PTR  ftp.example.com.
4  IN  PTR  ftp.example.com.
```

In this example, IP addresses `10.0.1.1` through `10.0.1.6` are pointed to the corresponding fully qualified domain name.

This zone file would be called into service with a **zone** statement in the **/etc/named.conf** file similar to the following:

```
zone "1.0.10.in-addr.arpa" IN {
  type master;
  file "example.com.rr.zone";
  allow-update { none; };
};
```

There is very little difference between this example and a standard **zone** statement, except for the zone name. Note that a reverse name resolution zone requires the first three blocks of the IP address reversed followed by **.in-addr.arpa**. This allows the single block of IP numbers used in the reverse name resolution zone file to be associated with the zone.

12.2.3. Using the rndc Utility

The **rndc** utility is a command line tool that allows you to administer the `named` service, both locally and from a remote machine. Its usage is as follows:

```
rndc [option...] command [command-option]
```

12.2.3.1. Configuring the Utility

To prevent unauthorized access to the service, `named` must be configured to listen on the selected port (that is, **953** by default), and an identical key must be used by both the service and the **rndc** utility.

Table 12.7. Relevant files

Path	Description
/etc/named.conf	The default configuration file for the `named` service.
/etc/rndc.conf	The default configuration file for the **rndc** utility.
/etc/rndc.key	The default key location.

The **rndc** configuration is located in **/etc/rndc.conf**. If the file does not exist, the utility will use the key located in **/etc/rndc.key**, which was generated automatically during the installation process using the **rndc-confgen -a** command.

The named service is configured using the **controls** statement in the **/etc/named.conf** configuration file as described in *Section 12.2.1.2, "Other Statement Types"*. Unless this statement is present, only the connections from the loopback address (that is, 127.0.0.1) will be allowed, and the key located in **/etc/rndc.key** will be used.

For more information on this topic, refer to manual pages and the *BIND 9 Administrator Reference Manual* listed in *Section 12.2.7, "Additional Resources"*.



Set the correct permissions

To prevent unprivileged users from sending control commands to the service, make sure only root is allowed to read the **/etc/rndc.key** file:

```
~]# chmod o-rwx /etc/rndc.key
```

12.2.3.2. Checking the Service Status

To check the current status of the named service, use the following command:

```
~]# rndc status
version: 9.7.0-P2-RedHat-9.7.0-5.P2.el6
CPUs found: 1
worker threads: 1
number of zones: 16
debug level: 0
xfers running: 0
xfers deferred: 0
soa queries in progress: 0
query logging is OFF
recursive clients: 0/0/1000
tcp clients: 0/100
server is up and running
```

12.2.3.3. Reloading the Configuration and Zones

To reload both the configuration file and zones, type the following at a shell prompt:

```
~]# rndc reload
server reload successful
```

This will reload the zones while keeping all previously cached responses, so that you can make changes to the zone files without losing all stored name resolutions.

To reload a single zone, specify its name after the **reload** command, for example:

```
~]# rndc reload localhost
zone reload up-to-date
```

Finally, to reload the configuration file and newly added zones only, type:

```
~]# rndc reconfig
```



Modifying zones with dynamic DNS

If you intend to manually modify a zone that uses Dynamic DNS (DDNS), make sure you run the **freeze** command first:

```
~]# rndc freeze localhost
```

Once you are finished, run the **thaw** command to allow the DDNS again and reload the zone:

```
~]# rndc thaw localhost
The zone reload and thaw was successful.
```

12.2.3.4. Updating Zone Keys

To update the DNSSEC keys and sign the zone, use the **sign** command. For example:

```
~]# rndc sign localhost
```

Note that to sign a zone with the above command, the **auto-dnssec** option has to be set to **maintain** in the zone statement. For instance:

```
zone "localhost" IN {
  type master;
  file "named.localhost";
  allow-update { none; };
  auto-dnssec maintain;
};
```

12.2.3.5. Enabling the DNSSEC Validation

To enable the DNSSEC validation, type the following at a shell prompt:

```
~]# rndc validation on
```

Similarly, to disable this option, type:

```
~]# rndc validation off
```

Refer to the **options** statement described in *Section 12.2.1.1, "Common Statement Types"* for information on how configure this option in **/etc/named.conf**.

12.2.3.6. Enabling the Query Logging

To enable (or disable in case it is currently enabled) the query logging, run the following command:

```
~]# rndc querylog
```

To check the current setting, use the **status** command as described in *Section 12.2.3.2, "Checking the Service Status"*.

12.2.4. Using the dig Utility

The **dig** utility is a command line tool that allows you to perform DNS lookups and debug a nameserver configuration. Its typical usage is as follows:

```
dig [@server] [option...] name type
```

Refer to *Section 12.2.2.2, "Common Resource Records"* for a list of common *type*s.

12.2.4.1. Looking Up a Nameserver

To look up a nameserver for a particular domain, use the command in the following form:

```
dig name NS
```

In *Example 12.16, "A sample nameserver lookup"*, the **dig** utility is used to display nameservers for `example.com`.

Example 12.16. A sample nameserver lookup

```
~]$ dig example.com NS

; <<>> DiG 9.7.1-P2-RedHat-9.7.1-2.P2.fc13 <<>> example.com NS
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 57883
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 0

;; QUESTION SECTION:
;example.com.                   IN      NS

;; ANSWER SECTION:
example.com.            99374   IN      NS      a.iana-servers.net.
example.com.            99374   IN      NS      b.iana-servers.net.

;; Query time: 1 msec
;; SERVER: 10.34.255.7#53(10.34.255.7)
;; WHEN: Wed Aug 18 18:04:06 2010
;; MSG SIZE  rcvd: 77
```

12.2.4.2. Looking Up an IP Address

To look up an IP address assigned to a particular domain, use the command in the following form:

```
dig name A
```

In *Example 12.17, "A sample IP address lookup"*, the **dig** utility is used to display the IP address of `example.com`.

Example 12.17. A sample IP address lookup

```
~]$ dig example.com A
```

```
; <<>> DiG 9.7.1-P2-RedHat-9.7.1-2.P2.fc13 <<>> example.com A
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 4849
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 0

;; QUESTION SECTION:
;example.com.                   IN      A

;; ANSWER SECTION:
example.com.            155606  IN      A       192.0.32.10

;; AUTHORITY SECTION:
example.com.            99175   IN      NS      a.iana-servers.net.
example.com.            99175   IN      NS      b.iana-servers.net.

;; Query time: 1 msec
;; SERVER: 10.34.255.7#53(10.34.255.7)
;; WHEN: Wed Aug 18 18:07:25 2010
;; MSG SIZE  rcvd: 93
```

12.2.4.3. Looking Up a Hostname

To look up a hostname for a particular IP address, use the command in the following form:

```
dig -x address
```

In *Example 12.18, "A sample hostname lookup"*, the **dig** utility is used to display the hostname assigned to `192.0.32.10`.

Example 12.18. A sample hostname lookup

```
~]$ dig -x 192.0.32.10

; <<>> DiG 9.7.1-P2-RedHat-9.7.1-2.P2.fc13 <<>> -x 192.0.32.10
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 29683
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 5, ADDITIONAL: 6

;; QUESTION SECTION:
;10.32.0.192.in-addr.arpa.      IN      PTR

;; ANSWER SECTION:
10.32.0.192.in-addr.arpa. 21600 IN      PTR     www.example.com.

;; AUTHORITY SECTION:
32.0.192.in-addr.arpa.  21600   IN      NS      b.iana-servers.org.
32.0.192.in-addr.arpa.  21600   IN      NS      c.iana-servers.net.
32.0.192.in-addr.arpa.  21600   IN      NS      d.iana-servers.net.
32.0.192.in-addr.arpa.  21600   IN      NS      ns.icann.org.
32.0.192.in-addr.arpa.  21600   IN      NS      a.iana-servers.net.

;; ADDITIONAL SECTION:
a.iana-servers.net.     13688   IN      A       192.0.34.43
b.iana-servers.org.     5844    IN      A       193.0.0.236
b.iana-servers.org.     5844    IN      AAAA    2001:610:240:2::c100:ec
c.iana-servers.net.     12173   IN      A       139.91.1.10
c.iana-servers.net.     12173   IN      AAAA    2001:648:2c30::1:10
ns.icann.org.           12884   IN      A       192.0.34.126

;; Query time: 156 msec
```

```
;; SERVER: 10.34.255.7#53(10.34.255.7)
;; WHEN: Wed Aug 18 18:25:15 2010
;; MSG SIZE  rcvd: 310
```

12.2.5. Advanced Features of BIND

Most BIND implementations only use the `named` service to provide name resolution services or to act as an authority for a particular domain. However, BIND version 9 has a number of advanced features that allow for a more secure and efficient DNS service.



Make sure the feature is supported

Before attempting to use advanced features like DNSSEC, TSIG, or IXFR, make sure that the particular feature is supported by all nameservers in the network environment, especially when you use older versions of BIND or non-BIND servers.

All of the features mentioned are discussed in greater detail in the *BIND 9 Administrator Reference Manual* referenced in *Section 12.2.7.1, "Installed Documentation"*.

12.2.5.1. Multiple Views

Optionally, different information can be presented to a client depending on the network a request originates from. This is primarily used to deny sensitive DNS entries from clients outside of the local network, while allowing queries from clients inside the local network.

To configure multiple views, add the **`view`** statement to the **`/etc/named.conf`** configuration file. Use the **`match-clients`** option to match IP addresses or entire networks and give them special options and zone data.

12.2.5.2. Incremental Zone Transfers (IXFR)

Incremental Zone Transfers (*IXFR*) allow a secondary nameserver to only download the updated portions of a zone modified on a primary nameserver. Compared to the standard transfer process, this makes the notification and update process much more efficient.

Note that IXFR is only available when using dynamic updating to make changes to master zone records. If manually editing zone files to make changes, *Automatic Zone Transfer* (*AXFR*) is used.

12.2.5.3. Transaction SIGnatures (TSIG)

Transaction SIGnatures (TSIG) ensure that a shared secret key exists on both primary and secondary nameserver before allowing a transfer. This strengthens the standard IP address-based method of transfer authorization, since attackers would not only need to have access to the IP address to transfer the zone, but they would also need to know the secret key.

Since version 9, BIND also supports *TKEY*, which is another shared secret key method of authorizing zone transfers.



Secure the transfer

When communicating over an insecure network, do not rely on IP address-based authentication only.

12.2.5.4. DNS Security Extensions (DNSSEC)

Domain Name System Security Extensions (*DNSSEC*) provide origin authentication of DNS data, authenticated denial of existence, and data integrity. When a particular domain is marked as secure, the **SERFVAIL** response is returned for each resource record that fails the validation.

Note that to debug a DNSSEC-signed domain or a DNSSEC-aware resolver, you can use the **dig** utility as described in *Section 12.2.4, "Using the dig Utility"*. Useful options are **+dnssec** (requests DNSSEC-related resource records by setting the DNSSEC OK bit), **+cd** (tells recursive nameserver not to validate the response), and **+bufsize=512** (changes the packet size to 512B to get through some firewalls).

12.2.5.5. Internet Protocol version 6 (IPv6)

Internet Protocol version 6 (*IPv6*) is supported through the use of **AAAA** resource records, and the **listen-on-v6** directive as described in *Table 12.3, "Commonly used options"*.

12.2.6. Common Mistakes to Avoid

The following is a list of advices how to avoid common mistakes users make when configuring a nameserver:

Use semicolons and curly brackets correctly
: An omitted semicolon or unmatched curly bracket in the **/etc/named.conf** file can prevent the `named` service from starting.

Use period (that is, the **.** character) correctly
: In zone files, a period at the end of a domain name denotes a fully qualified domain name. If omitted, the `named` service will append the name of the zone or the value of **$ORIGIN** to complete it.

Increment the serial number when editing a zone file
: If the serial number is not incremented, the primary nameserver will have the correct, new information, but the secondary nameservers will never be notified of the change, and will not attempt to refresh their data of that zone.

Configure the firewall
: If a firewall is blocking connections from the `named` service to other nameservers, the recommended best practice is to change the firewall settings whenever possible.



Avoid using fixed UDP source ports

According to the recent research in DNS security, using a fixed UDP source port for DNS queries is a potential security vulnerability that could allow an attacker to conduct cache-poisoning attacks more easily. To prevent this, configure your firewall to allow queries from a random UDP source port.

12.2.7. Additional Resources

The following sources of information provide additional resources regarding BIND.

12.2.7.1. Installed Documentation

BIND features a full range of installed documentation covering many different topics, each placed in its own subject directory. For each item below, replace *`version`* with the version of the *bind* package installed on the system:

`/usr/share/doc/bind-`*`version`*`/`
The main directory containing the most recent documentation.

`/usr/share/doc/bind-`*`version`*`/arm/`
The directory containing the *BIND 9 Administrator Reference Manual* in HTML and SGML formats, which details BIND resource requirements, how to configure different types of nameservers, how to perform load balancing, and other advanced topics. For most new users of BIND, this is the best place to start.

`/usr/share/doc/bind-`*`version`*`/draft/`
The directory containing assorted technical documents that review issues related to the DNS service, and propose some methods to address them.

`/usr/share/doc/bind-`*`version`*`/misc/`
The directory designed to address specific advanced issues. Users of BIND version 8 should consult the **`migration`** document for specific changes they must make when moving to BIND 9. The **`options`** file lists all of the options implemented in BIND 9 that are used in **`/etc/named.conf`**.

`/usr/share/doc/bind-`*`version`*`/rfc/`
The directory providing every RFC document related to BIND.

There is also a number of man pages for the various applications and configuration files involved with BIND:

`man rndc`
The manual page for **`rndc`** containing the full documentation on its usage.

`man named`
The manual page for `named` containing the documentation on assorted arguments that can be used to control the BIND nameserver daemon.

`man lwresd`
The manual page for `lwresd` containing the full documentation on the lightweight resolver daemon and its usage.

`man named.conf`
The manual page with a comprehensive list of options available within the `named` configuration file.

`man rndc.conf`
The manual page with a comprehensive list of options available within the **`rndc`** configuration file.

12.2.7.2. Useful Websites

http://www.isc.org/software/bind
The home page of the BIND project containing information about current releases as well as a PDF version of the *BIND 9 Administrator Reference Manual*.

12.2.7.3. Related Books

DNS and BIND by Paul Albitz and Cricket Liu; O'Reilly & Associates
A popular reference that explains both common and esoteric BIND configuration options, and provides strategies for securing a DNS server.

The Concise Guide to DNS and BIND by Nicolai Langfeldt; Que
Looks at the connection between multiple network services and BIND, with an emphasis on task-oriented, technical topics.

Web Servers

HTTP (Hypertext Transfer Protocol) server, or a *web server*, is a network service that serves content to a client over the web. This typically means web pages, but any other documents can be served as well.

13.1. The Apache HTTP Server

This section focuses on the **Apache HTTP Server 2.2**, a robust, full-featured open source web server developed by the *Apache Software Foundation*[1], that is included in Fedora 17. It describes the basic configuration of the `httpd` service, and covers advanced topics such as adding server modules, setting up virtual hosts, or configuring the secure HTTP server.

There are important differences between the Apache HTTP Server 2.2 and version 2.0, and if you are upgrading from a previous release of Fedora, you will need to update the `httpd` service configuration accordingly. This section reviews some of the newly added features, outlines important changes, and guides you through the update of older configuration files.

13.1.1. New Features

The Apache HTTP Server version 2.2 introduces the following enhancements:

- Improved caching modules, that is, `mod_cache` and `mod_disk_cache`.
- Support for proxy load balancing, that is, the `mod_proxy_balancer` module.
- Support for large files on 32-bit architectures, allowing the web server to handle files greater than 2GB.
- A new structure for authentication and authorization support, replacing the authentication modules provided in previous versions.

13.1.2. Notable Changes

Since version 2.0, few changes have been made to the default `httpd` service configuration:

- The following modules are no longer loaded by default: `mod_cern_meta` and `mod_asis`.
- The following module is newly loaded by default: `mod_ext_filter`.

13.1.3. Updating the Configuration

To update the configuration files from the Apache HTTP Server version 2.0, take the following steps:

1. Make sure all module names are correct, since they may have changed. Adjust the **`LoadModule`** directive for each module that has been renamed.

[1] http://www.apache.org/

2. Recompile all third party modules before attempting to load them. This typically means authentication and authorization modules.

3. If you use the `mod_userdir` module, make sure the **`UserDir`** directive indicating a directory name (typically **`public_html`**) is provided.

4. If you use the Apache HTTP Secure Server, edit the **`/etc/httpd/conf.d/ssl.conf`** to enable the Secure Sockets Layer (SSL) protocol.

Note that you can check the configuration for possible errors by using the following command:

```
service httpd configtest
```

For more information on upgrading the Apache HTTP Server configuration from version 2.0 to 2.2, refer to *http://httpd.apache.org/docs/2.2/upgrading.html*.

13.1.4. Running the httpd Service

This section describes how to start, stop, restart, and check the current status of the Apache HTTP Server. To be able to use the `httpd` service, make sure you have the *httpd* installed. You can do so by using the following command as `root`:

```
yum install httpd
```

For more information on the concept of runlevels and how to manage system services in Fedora in general, refer to *Chapter 8, Services and Daemons*.

13.1.4.1. Starting the Service

To run the `httpd` service, type the following at a shell prompt as `root`:

```
systemctl start httpd.service
```

If you want the service to start automatically at the boot time, use the following command:

```
systemctl enable httpd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.



Using the secure server

If running the Apache HTTP Server as a secure server, a password may be required after the machine boots if using an encrypted private SSL key.

13.1.4.2. Stopping the Service

To stop the running `httpd` service, type the following at a shell prompt as `root`:

```
systemctl stop httpd.service
```

To prevent the service from starting automatically at the boot time, type:

```
systemctl disable httpd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

13.1.4.3. Restarting the Service

There are two different ways to restart the running `httpd` service:

1. To restart the service completely, type the following at a shell prompt as `root`:

   ```
   systemctl restart httpd.service
   ```

   This will stop the running `httpd` service, and then start it again. Use this command after installing or removing a dynamically loaded module such as PHP.

2. To only reload the configuration, as `root`, type:

   ```
   systemctl reload httpd.service
   ```

   This will cause the running `httpd` service to reload the configuration file. Note that any requests being currently processed will be interrupted, which may cause a client browser to display an error message or render a partial page.

3. To reload the configuration without affecting active requests, run the following command as `root`:

   ```
   service httpd graceful
   ```

   This will cause the running `httpd` service to reload the configuration file. Note that any requests being currently processed will use the old configuration.

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

13.1.4.4. Checking the Service Status

To check whether the service is running, type the following at a shell prompt:

```
systemctl is-active httpd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

13.1.5. Editing the Configuration Files

When the `httpd` service is started, by default, it reads the configuration from locations that are listed in *Table 13.1, "The httpd service configuration files"*.

Table 13.1. The httpd service configuration files

Path	Description
/etc/httpd/conf/httpd.conf	The main configuration file.
/etc/httpd/conf.d/	An auxiliary directory for configuration files that are included in the main configuration file.

Although the default configuration should be suitable for most situations, it is a good idea to become at least familiar with some of the more important configuration options. Note that for any changes to take effect, the web server has to be restarted first. Refer to *Section 13.1.4.3, "Restarting the Service"* for more information on how to restart the `httpd` service.

To check the configuration for possible errors, type the following at a shell prompt:

```
service httpd configtest
```

To make the recovery from mistakes easier, it is recommended that you make a copy of the original file before editing it.

13.1.5.1. Common httpd.conf Directives

The following directives are commonly used in the **/etc/httpd/conf/httpd.conf** configuration file:

<Directory>

The **<Directory>** directive allows you to apply certain directives to a particular directory only. It takes the following form:

```
<Directory directory>
  directive
  …
</Directory>
```

The *directory* can be either a full path to an existing directory in the local file system, or a wildcard expression.

This directive can be used to configure additional **cgi-bin** directories for server-side scripts located outside the directory that is specified by **ScriptAlias**. In this case, the **ExecCGI** and **AddHandler** directives must be supplied, and the permissions on the target directory must be set correctly (that is, **0755**).

Example 13.1. Using the <Directory> directive

```
<Directory /var/www/html>
  Options Indexes FollowSymLinks
  AllowOverride None
  Order allow,deny
  Allow from all
</Directory>
```

<IfDefine>

The **IfDefine** directive allows you to use certain directives only when a particular parameter is supplied on the command line. It takes the following form:

```
<IfDefine [!]parameter>
  directive
  …
</IfDefine>
```

The *parameter* can be supplied at a shell prompt using the **-D***parameter* command line option (for example, **httpd -DEnableHome**). If the optional exclamation mark (that is, **!**) is present, the enclosed directives are used only when the parameter is *not* specified.

Example 13.2. Using the <IfDefine> directive

```
<IfDefine EnableHome>
  UserDir public_html
</IfDefine>
```

<IfModule>

The **<IfModule>** directive allows you to use certain directive only when a particular module is loaded. It takes the following form:

```
<IfModule [!]module>
  directive
  …
</IfModule>
```

The *module* can be identified either by its name, or by the file name. If the optional exclamation mark (that is, **!**) is present, the enclosed directives are used only when the module is *not* loaded.

Example 13.3. Using the <IfModule> directive

```
<IfModule mod_disk_cache.c>
  CacheEnable disk /
  CacheRoot /var/cache/mod_proxy
</IfModule>
```

<Location>

The **<Location>** directive allows you to apply certain directives to a particular URL only. It takes the following form:

```
<Location url>
  directive
  …
</Location>
```

The *url* can be either a path relative to the directory specified by the **DocumentRoot** directive (for example, **/server-info**), or an external URL such as **http://example.com/server-info**.

Example 13.4. Using the <Location> directive

```
<Location /server-info>
  SetHandler server-info
  Order deny,allow
  Deny from all
  Allow from .example.com
```

```
</Location>
```

<Proxy>

The **<Proxy>** directive allows you to apply certain directives to the proxy server only. It takes the following form:

```
<Proxy pattern>
  directive
  …
</Proxy>
```

The *pattern* can be an external URL, or a wildcard expression (for example, **http://example.com/***).

Example 13.5. Using the <Proxy> directive

```
<Proxy *>
  Order deny,allow
  Deny from all
  Allow from .example.com
</Proxy>
```

<VirtualHost>

The **<VirtualHost>** directive allows you apply certain directives to particular virtual hosts only. It takes the following form:

```
<VirtualHost address[:port]…>
  directive
  …
</VirtualHost>
```

The *address* can be an IP address, a fully qualified domain name, or a special form as described in *Table 13.2, "Available <VirtualHost> options"*.

Table 13.2. Available <VirtualHost> options

Option	Description
*	Represents all IP addresses.
default	Represents unmatched IP addresses.

Example 13.6. Using the <VirtualHost> directive

```
<VirtualHost *:80>
  ServerAdmin webmaster@penguin.example.com
  DocumentRoot /www/docs/penguin.example.com
  ServerName penguin.example.com
  ErrorLog logs/penguin.example.com-error_log
  CustomLog logs/penguin.example.com-access_log common
</VirtualHost>
```

AccessFileName

The **AccessFileName** directive allows you to specify the file to be used to customize access control information for each directory. It takes the following form:

```
AccessFileName filename…
```

The *filename* is a name of the file to look for in the requested directory. By default, the server looks for **.htaccess**.

For security reasons, the directive is typically followed by the **Files** tag to prevent the files beginning with **.ht** from being accessed by web clients. This includes the **.htaccess** and **.htpasswd** files.

Example 13.7. Using the AccessFileName directive

```
AccessFileName .htaccess

<Files ~ "^\.ht">
  Order allow,deny
  Deny from all
  Satisfy All
</Files>
```

Action

The **Action** directive allows you to specify a CGI script to be executed when a certain media type is requested. It takes the following form:

```
Action content-type path
```

The *content-type* has to be a valid MIME type such as **text/html**, **image/png**, or **application/pdf**. The *path* refers to an existing CGI script, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/cgi-bin/process-image.cgi**).

Example 13.8. Using the Action directive

```
Action image/png /cgi-bin/process-image.cgi
```

AddDescription

The **AddDescription** directive allows you to specify a short description to be displayed in server-generated directory listings for a given file. It takes the following form:

```
AddDescription "description" filename…
```

The *description* should be a short text enclosed in double quotes (that is, **"**). The *filename* can be a full file name, a file extension, or a wildcard expression.

Example 13.9. Using the AddDescription directive

```
AddDescription "GZIP compressed tar archive" .tgz
```

AddEncoding

The **AddEncoding** directive allows you to specify an encoding type for a particular file extension. It takes the following form:

```
AddEncoding encoding extension…
```

The *encoding* has to be a valid MIME encoding such as **x-compress**, **x-gzip**, etc. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, **.gz**).

This directive is typically used to instruct web browsers to decompress certain file types as they are downloaded.

Example 13.10. Using the AddEncoding directive

```
AddEncoding x-gzip .gz .tgz
```

AddHandler

The **AddHandler** directive allows you to map certain file extensions to a selected handler. It takes the following form:

```
AddHandler handler extension…
```

The *handler* has to be a name of previously defined handler. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, **.cgi**).

This directive is typically used to treat files with the **.cgi** extension as CGI scripts regardless of the directory they are in. Additionally, it is also commonly used to process server-parsed HTML and image-map files.

Example 13.11. Using the AddHandler option

```
AddHandler cgi-script .cgi
```

AddIcon

The **AddIcon** directive allows you to specify an icon to be displayed for a particular file in server-generated directory listings. It takes the following form:

```
AddIcon path pattern…
```

The *path* refers to an existing icon file, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/icons/folder.png**). The *pattern* can be a file name, a file extension, a wildcard expression, or a special form as described in the following table:

Table 13.3. Available AddIcon options

Option	Description
^^DIRECTORY^^	Represents a directory.
^^BLANKICON^^	Represents a blank line.

Example 13.12. Using the AddIcon directive

```
AddIcon /icons/text.png .txt README
```

AddIconByEncoding

The **AddIconByEncoding** directive allows you to specify an icon to be displayed for a particular encoding type in server-generated directory listings. It takes the following form:

```
AddIconByEncoding path encoding…
```

The *path* refers to an existing icon file, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/icons/compressed.png**). The *encoding* has to be a valid MIME encoding such as **x-compress**, **x-gzip**, etc.

Example 13.13. Using the AddIconByEncoding directive

```
AddIconByEncoding /icons/compressed.png x-compress x-gzip
```

AddIconByType

The **AddIconByType** directive allows you to specify an icon to be displayed for a particular media type in server-generated directory listings. It takes the following form:

```
AddIconByType path content-type…
```

The *path* refers to an existing icon file, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/icons/text.png**). The *content-type* has to be either a valid MIME type (for example, **text/html** or **image/png**), or a wildcard expression such as **text/***, **image/***, etc.

Example 13.14. Using the AddIconByType directive

```
AddIconByType /icons/video.png video/*
```

AddLanguage

The **AddLanguage** directive allows you to associate a file extension with a specific language. It takes the following form:

```
AddLanguage language extension…
```

The *language* has to be a valid MIME language such as **cs**, **en**, or **fr**. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, **.cs**).

This directive is especially useful for web servers that serve content in multiple languages based on the client's language settings.

Example 13.15. Using the AddLanguage directive

```
AddLanguage cs .cs .cz
```

AddType

The **AddType** directive allows you to define or override the media type for a particular file extension. It takes the following form:

```
AddType content-type extension…
```

The *content-type* has to be a valid MIME type such as **text/html**, **image/png**, etc. The *extension* is a case sensitive file extension, and is conventionally written with a leading dot (for example, **.cs**).

> Example 13.16. Using the AddType directive
>
> ```
> AddType application/x-gzip .gz .tgz
> ```

Alias

The **Alias** directive allows you to refer to files and directories outside the default directory specified by the **DocumentRoot** directive. It takes the following form:

```
Alias url-path real-path
```

The *url-path* must be relative to the directory specified by the **DocumentRoot** directive (for example, **/images/**). The *real-path* is a full path to a file or directory in the local file system.

This directive is typically followed by the **Directory** tag with additional permissions to access the target directory. By default, the **/icons/** alias is created so that the icons from **/var/www/icons/** are displayed in server-generated directory listings.

> Example 13.17. Using the Alias directive
>
> ```
> Alias /icons/ /var/www/icons/
>
> <Directory "/var/www/icons">
>   Options Indexes MultiViews FollowSymLinks
>   AllowOverride None
>   Order allow,deny
>   Allow from all
> <Directory>
> ```

Allow

The **Allow** directive allows you to specify which clients have permission to access a given directory. It takes the following form:

```
Allow from client…
```

The *client* can be a domain name, an IP address (both full and partial), a *network*/*netmask* pair, or **all** for all clients.

> Example 13.18. Using the Allow directive
>
> ```
> Allow from 192.168.1.0/255.255.255.0
> ```

AllowOverride

The **AllowOverride** directive allows you to specify which directives in a **.htaccess** file can override the default configuration. It takes the following form:

```
AllowOverride type…
```

The *type* has to be one of the available grouping options as described in *Table 13.4, "Available AllowOverride options"*.

Table 13.4. Available AllowOverride options

Option	Description
All	All directives in **.htaccess** are allowed to override earlier configuration settings.
None	No directive in **.htaccess** is allowed to override earlier configuration settings.
AuthConfig	Allows the use of authorization directives such as **AuthName**, **AuthType**, or **Require**.
FileInfo	Allows the use of file type, metadata, and `mod_rewrite` directives such as **DefaultType**, **RequestHeader**, or **RewriteEngine**, as well as the **Action** directive.
Indexes	Allows the use of directory indexing directives such as **AddDescription**, **AddIcon**, or **FancyIndexing**.
Limit	Allows the use of host access directives, that is, **Allow**, **Deny**, and **Order**.
Options[=*option*, …]	Allows the use of the **Options** directive. Additionally, you can provide a comma-separated list of options to customize which options can be set using this directive.

Example 13.19. Using the AllowOverride directive

```
AllowOverride FileInfo AuthConfig Limit
```

BrowserMatch

The **BrowserMatch** directive allows you to modify the server behavior based on the client's web browser type. It takes the following form:

```
BrowserMatch pattern variable…
```

The *pattern* is a regular expression to match the User-Agent HTTP header field. The *variable* is an environment variable that is set when the header field matches the pattern.

By default, this directive is used to deny connections to specific browsers with known issues, and to disable keepalives and HTTP header flushes for browsers that are known to have problems with these actions.

Example 13.20. Using the BrowserMatch directive

```
BrowserMatch "Mozilla/2" nokeepalive
```

CacheDefaultExpire

The **CacheDefaultExpire** option allows you to set how long to cache a document that does not have any expiration date or the date of its last modification specified. It takes the following form:

```
CacheDefaultExpire time
```

The *time* is specified in seconds. The default option is **3600** (that is, one hour).

Example 13.21. Using the CacheDefaultExpire directive

```
CacheDefaultExpire 3600
```

CacheDisable

The **CacheDisable** directive allows you to disable caching of certain URLs. It takes the following form:

```
CacheDisable path
```

The *path* must be relative to the directory specified by the **DocumentRoot** directive (for example, **/files/**).

Example 13.22. Using the CacheDisable directive

```
CacheDisable /temporary
```

CacheEnable

The **CacheEnable** directive allows you to specify a cache type to be used for certain URLs. It takes the following form:

```
CacheEnable type url
```

The *type* has to be a valid cache type as described in *Table 13.5, "Available cache types"*.
The *url* can be a path relative to the directory specified by the **DocumentRoot** directive (for example, **/images/**), a protocol (for example, **ftp://**), or an external URL such as **http://example.com/**.

Table 13.5. Available cache types

Type	Description
mem	The memory-based storage manager.
disk	The disk-based storage manager.
fd	The file descriptor cache.

Example 13.23. Using the CacheEnable directive

```
CacheEnable disk /
```

CacheLastModifiedFactor

The **CacheLastModifiedFactor** directive allows you to customize how long to cache a document that does not have any expiration date specified, but that provides information about the date of its last modification. It takes the following form:

```
CacheLastModifiedFactor number
```

The *number* is a coefficient to be used to multiply the time that passed since the last modification of the document. The default option is **0.1** (that is, one tenth).

Example 13.24. Using the CacheLastModifiedFactor directive

```
CacheLastModifiedFactor 0.1
```

CacheMaxExpire

The **CacheMaxExpire** directive allows you to specify the maximum amount of time to cache a document. It takes the following form:

```
CacheMaxExpire time
```

The *time* is specified in seconds. The default option is **86400** (that is, one day).

Example 13.25. Using the CacheMaxExpire directive

```
CacheMaxExpire 86400
```

CacheNegotiatedDocs

The **CacheNegotiatedDocs** directive allows you to enable caching of the documents that were negotiated on the basis of content. It takes the following form:

```
CacheNegotiatedDocs option
```

The *option* has to be a valid keyword as described in *Table 13.6, "Available CacheNegotiatedDocs options"*. Since the content-negotiated documents may change over time or because of the input from the requester, the default option is **Off**.

Table 13.6. Available CacheNegotiatedDocs options

Option	Description
On	Enables caching the content-negotiated documents.
Off	Disables caching the content-negotiated documents.

Example 13.26. Using the CacheNegotiatedDocs directive

```
CacheNegotiatedDocs On
```

CacheRoot

The **CacheRoot** directive allows you to specify the directory to store cache files in. It takes the following form:

```
CacheRoot directory
```

The *directory* must be a full path to an existing directory in the local file system. The default option is **/var/cache/mod_proxy/**.

> Example 13.27. Using the CacheRoot directive
>
> ```
> CacheRoot /var/cache/mod_proxy
> ```

CustomLog

The **CustomLog** directive allows you to specify the log file name and the log file format. It takes the following form:

```
CustomLog path format
```

The *path* refers to a log file, and must be relative to the directory that is specified by the **ServerRoot** directive (that is, **/etc/httpd/** by default). The *format* has to be either an explicit format string, or a format name that was previously defined using the **LogFormat** directive.

> Example 13.28. Using the CustomLog directive
>
> ```
> CustomLog logs/access_log combined
> ```

DefaultIcon

The **DefaultIcon** directive allows you to specify an icon to be displayed for a file in server-generated directory listings when no other icon is associated with it. It takes the following form:

```
DefaultIcon path
```

The *path* refers to an existing icon file, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/icons/unknown.png**).

> Example 13.29. Using the DefaultIcon directive
>
> ```
> DefaultIcon /icons/unknown.png
> ```

DefaultType

The **DefaultType** directive allows you to specify a media type to be used in case the proper MIME type cannot be determined by the server. It takes the following form:

```
DefaultType content-type
```

The *content-type* has to be a valid MIME type such as **text/html**, **image/png**, **application/pdf**, etc.

Example 13.30. Using the DefaultType directive

```
DefaultType text/plain
```

Deny

The **Deny** directive allows you to specify which clients are denied access to a given directory. It takes the following form:

```
Deny from client…
```

The *client* can be a domain name, an IP address (both full and partial), a *network*/*netmask* pair, or **all** for all clients.

Example 13.31. Using the Deny directive

```
Deny from 192.168.1.1
```

DirectoryIndex

The **DirectoryIndex** directive allows you to specify a document to be served to a client when a directory is requested (that is, when the URL ends with the / character). It takes the following form:

```
DirectoryIndex filename…
```

The *filename* is a name of the file to look for in the requested directory. By default, the server looks for **index.html**, and **index.html.var**.

Example 13.32. Using the DirectoryIndex directive

```
DirectoryIndex index.html index.html.var
```

DocumentRoot

The **DocumentRoot** directive allows you to specify the main directory from which the content is served. It takes the following form:

```
DocumentRoot directory
```

The *directory* must be a full path to an existing directory in the local file system. The default option is **/var/www/html/**.

Example 13.33. Using the DocumentRoot directive

```
DocumentRoot /var/www/html
```

ErrorDocument

The **ErrorDocument** directive allows you to specify a document or a message to be displayed as a response to a particular error. It takes the following form:

```
ErrorDocument error-code action
```

The *error-code* has to be a valid code such as **403** (Forbidden), **404** (Not Found), or **500** (Internal Server Error). The *action* can be either a URL (both local and external), or a message string enclosed in double quotes (that is, **"**).

Example 13.34. Using the ErrorDocument directive

```
ErrorDocument 403 "Access Denied"
ErrorDocument 404 /404-not_found.html
```

ErrorLog

The **ErrorLog** directive allows you to specify a file to which the server errors are logged. It takes the following form:

```
ErrorLog path
```

The *path* refers to a log file, and can be either absolute, or relative to the directory that is specified by the **ServerRoot** directive (that is, **/etc/httpd/** by default). The default option is **logs/error_log**

Example 13.35. Using the ErrorLog directive

```
ErrorLog logs/error_log
```

ExtendedStatus

The **ExtendedStatus** directive allows you to enable detailed server status information. It takes the following form:

```
ExtendedStatus option
```

The *option* has to be a valid keyword as described in *Table 13.7, "Available ExtendedStatus options"*. The default option is **Off**.

Table 13.7. Available ExtendedStatus options

Option	Description
On	Enables generating the detailed server status.
Off	Disables generating the detailed server status.

Example 13.36. Using the ExtendedStatus directive

```
ExtendedStatus On
```

Group

The **Group** directive allows you to specify the group under which the `httpd` service will run. It takes the following form:

```
Group group
```

The *group* has to be an existing UNIX group. The default option is **apache**.

Note that **Group** is no longer supported inside **<VirtualHost>**, and has been replaced by the **SuexecUserGroup** directive.

Example 13.37. Using the Group directive

```
Group apache
```

HeaderName

The **HeaderName** directive allows you to specify a file to be prepended to the beginning of the server-generated directory listing. It takes the following form:

```
HeaderName filename
```

The *filename* is a name of the file to look for in the requested directory. By default, the server looks for **HEADER.html**.

Example 13.38. Using the HeaderName directive

```
HeaderName HEADER.html
```

HostnameLookups

The **HostnameLookups** directive allows you to enable automatic resolving of IP addresses. It takes the following form:

```
HostnameLookups option
```

The *option* has to be a valid keyword as described in *Table 13.8, "Available HostnameLookups options"*. To conserve resources on the server, the default option is **Off**.

Table 13.8. Available HostnameLookups options

Option	Description
On	Enables resolving the IP address for each connection so that the hostname can be logged. However, this also adds a significant processing overhead.
Double	Enables performing the double-reverse DNS lookup. In comparison to the above option, this adds even more processing overhead.
Off	Disables resolving the IP address for each connection.

Note that when the presence of hostnames is required in server log files, it is often possible to use one of the many log analyzer tools that perform the DNS lookups more efficiently.

Example 13.39. Using the HostnameLookups directive

```
HostnameLookups Off
```

Include

The **Include** directive allows you to include other configuration files. It takes the following form:

```
Include filename
```

The **filename** can be an absolute path, a path relative to the directory specified by the **ServerRoot** directive, or a wildcard expression. All configuration files from the **/etc/httpd/conf.d/** directory are loaded by default.

Example 13.40. Using the Include directive

```
Include conf.d/*.conf
```

IndexIgnore

The **IndexIgnore** directive allows you to specify a list of file names to be omitted from the server-generated directory listings. It takes the following form:

```
IndexIgnore filename…
```

The *filename* option can be either a full file name, or a wildcard expression.

Example 13.41. Using the IndexIgnore directive

```
IndexIgnore .??* *~ *# HEADER* README* RCS CVS *,v *,t
```

IndexOptions

The **IndexOptions** directive allows you to customize the behavior of server-generated directory listings. It takes the following form:

```
IndexOptions option…
```

The *option* has to be a valid keyword as described in *Table 13.9, "Available directory listing options"*. The default options are **Charset=UTF-8**, **FancyIndexing**, **HTMLTable**, **NameWidth=***, and **VersionSort**.

Table 13.9. Available directory listing options

Option	Description
Charset=*encoding*	Specifies the character set of a generated web page. The *encoding* has to be a valid character set such as **UTF-8** or **ISO-8859-2**.
Type=*content-type*	Specifies the media type of a generated web page. The *content-type* has to be a valid MIME type such as **text/html** or **text/plain**.
DescriptionWidth=*value*	Specifies the width of the description column. The *value* can be either a number of characters, or an asterisk (that is, *****) to adjust the width automatically.

Option	Description
FancyIndexing	Enables advanced features such as different icons for certain files or possibility to re-sort a directory listing by clicking on a column header.
FolderFirst	Enables listing directories first, always placing them above files.
HTMLTable	Enables the use of HTML tables for directory listings.
IconsAreLinks	Enables using the icons as links.
IconHeight=*value*	Specifies an icon height. The *value* is a number of pixels.
IconWidth=*value*	Specifies an icon width. The *value* is a number of pixels.
IgnoreCase	Enables sorting files and directories in a case-sensitive manner.
IgnoreClient	Disables accepting query variables from a client.
NameWidth=*value*	Specifies the width of the file name column. The *value* can be either a number of characters, or an asterisk (that is, *****) to adjust the width automatically.
ScanHTMLTitles	Enables parsing the file for a description (that is, the **title** element) in case it is not provided by the **AddDescription** directive.
ShowForbidden	Enables listing the files with otherwise restricted access.
SuppressColumnSorting	Disables re-sorting a directory listing by clicking on a column header.
SuppressDescription	Disables reserving a space for file descriptions.
SuppressHTMLPreamble	Disables the use of standard HTML preamble when a file specified by the **HeaderName** directive is present.
SuppressIcon	Disables the use of icons in directory listings.
SuppressLastModified	Disables displaying the date of the last modification field in directory listings.
SuppressRules	Disables the use of horizontal lines in directory listings.
SuppressSize	Disables displaying the file size field in directory listings.
TrackModified	Enables returning the **Last-Modified** and **ETag** values in the HTTP header.
VersionSort	Enables sorting files that contain a version number in the expected manner.
XHTML	Enables the use of XHTML 1.0 instead of the default HTML 3.2.

Example 13.42. Using the IndexOptions directive

```
IndexOptions FancyIndexing VersionSort NameWidth=* HTMLTable Charset=UTF-8
```

KeepAlive

The **KeepAlive** directive allows you to enable persistent connections. It takes the following form:

```
KeepAlive option
```

The *option* has to be a valid keyword as described in *Table 13.10, "Available KeepAlive options"*. The default option is **Off**.

Table 13.10. Available KeepAlive options

Option	Description
On	Enables the persistent connections. In this case, the server will accept more than one request per connection.
Off	Disables the keep-alive connections.

Note that when the persistent connections are enabled, on a busy server, the number of child processes can increase rapidly and eventually reach the maximum limit, slowing down the server significantly. To reduce the risk, it is recommended that you set **KeepAliveTimeout** to a low number, and monitor the **/var/log/httpd/logs/error_log** log file carefully.

Example 13.43. Using the KeepAlive directive

```
KeepAlive Off
```

KeepAliveTimeout

The **KeepAliveTimeout** directive allows you to specify the amount of time to wait for another request before closing the connection. It takes the following form:

```
KeepAliveTimeout time
```

The *time* is specified in seconds. The default option is **15**.

Example 13.44. Using the KeepAliveTimeout directive

```
KeepAliveTimeout 15
```

LanguagePriority

The **LanguagePriority** directive allows you to customize the precedence of languages. It takes the following form:

```
LanguagePriority language…
```

The *language* has to be a valid MIME language such as **cs**, **en**, or **fr**.

This directive is especially useful for web servers that serve content in multiple languages based on the client's language settings.

Example 13.45. Using the LanguagePriority directive

```
LanguagePriority sk cs en
```

Listen

The *Listen* directive allows you to specify IP addresses or ports to listen to. It takes the following form:

```
Listen [ip-address:]port [protocol]
```

The *ip-address* is optional and unless supplied, the server will accept incoming requests on a given *port* from all IP addresses. Since the *protocol* is determined automatically from the port number, it can be usually omitted. The default option is to listen to port **80**.

Note that if the server is configured to listen to a port under 1024, only superuser will be able to start the `httpd` service.

Example 13.46. Using the Listen directive

```
Listen 80
```

LoadModule

The **LoadModule** directive allows you to load a *Dynamic Shared Object* (DSO) module. It takes the following form:

```
LoadModule name path
```

The *name* has to be a valid identifier of the required module. The *path* refers to an existing module file, and must be relative to the directory in which the libraries are placed (that is, **/usr/lib/httpd/** on 32-bit and **/usr/lib64/httpd/** on 64-bit systems by default).

Refer to *Section 13.1.6, "Working with Modules"* for more information on the Apache HTTP Server's DSO support.

Example 13.47. Using the LoadModule directive

```
LoadModule php5_module modules/libphp5.so
```

LogFormat

The *LogFormat* directive allows you to specify a log file format. It takes the following form:

```
LogFormat format name
```

The *format* is a string consisting of options as described in *Table 13.11, "Common LogFormat options"*. The *name* can be used instead of the format string in the **CustomLog** directive.

Table 13.11. Common LogFormat options

Option	Description
%b	Represents the size of the response in bytes.
%h	Represents the IP address or hostname of a remote client.
%l	Represents the remote log name if supplied. If not, a hyphen (that is, **-**) is used instead.
%r	Represents the first line of the request string as it came from the browser or client.
%s	Represents the status code.
%t	Represents the date and time of the request.
%u	If the authentication is required, it represents the remote user. If not, a hyphen (that is, **-**) is used instead.

Option	Description
%{*field*}	Represents the content of the HTTP header *field*. The common options include **%{Referer}** (the URL of the web page that referred the client to the server) and **%{User-Agent}** (the type of the web browser making the request).

Example 13.48. Using the LogFormat directive

```
LogFormat "%h %l %u %t \"%r\" %>s %b" common
```

LogLevel

The **LogLevel** directive allows you to customize the verbosity level of the error log. It takes the following form:

```
LogLevel option
```

The *option* has to be a valid keyword as described in *Table 13.12, "Available LogLevel options"*. The default option is **warn**.

Table 13.12. Available LogLevel options

Option	Description
emerg	Only the emergency situations when the server cannot perform its work are logged.
alert	All situations when an immediate action is required are logged.
crit	All critical conditions are logged.
error	All error messages are logged.
warn	All warning messages are logged.
notice	Even normal, but still significant situations are logged.
info	Various informational messages are logged.
debug	Various debugging messages are logged.

Example 13.49. Using the LogLevel directive

```
LogLevel warn
```

MaxKeepAliveRequests

The **MaxKeepAliveRequests** directive allows you to specify the maximum number of requests for a persistent connection. It takes the following form:

```
MaxKeepAliveRequests number
```

A high *number* can improve the performance of the server. Note that using **0** allows unlimited number of requests. The default option is **100**.

Example 13.50. Using the MaxKeepAliveRequests option

```
MaxKeepAliveRequests 100
```

NameVirtualHost

The **NameVirtualHost** directive allows you to specify the IP address and port number for a name-based virtual host. It takes the following form:

```
NameVirtualHost ip-address[:port]
```

The *ip-address* can be either a full IP address, or an asterisk (that is, *****) representing all interfaces. Note that IPv6 addresses have to be enclosed in square brackets (that is, **[** and **]**). The *port* is optional.

Name-based virtual hosting allows one Apache HTTP Server to serve different domains without using multiple IP addresses.



Using secure HTTP connections

Name-based virtual hosts *only* work with non-secure HTTP connections. If using virtual hosts with a secure server, use IP address-based virtual hosts instead.

Example 13.51. Using the NameVirtualHost directive

```
NameVirtualHost *:80
```

Options

The **Options** directive allows you to specify which server features are available in a particular directory. It takes the following form:

```
Options option…
```

The *option* has to be a valid keyword as described in *Table 13.13, "Available server features"*.

Table 13.13. Available server features

Option	Description
ExecCGI	Enables the execution of CGI scripts.
FollowSymLinks	Enables following symbolic links in the directory.
Includes	Enables server-side includes.
IncludesNOEXEC	Enables server-side includes, but does not allow the execution of commands.
Indexes	Enables server-generated directory listings.
MultiViews	Enables content-negotiated "MultiViews".
SymLinksIfOwnerMatch	Enables following symbolic links in the directory when both the link and the target file have the same owner.
All	Enables all of the features above with the exception of **MultiViews**.
None	Disables all of the features above.

Example 13.52. Using the Options directive

```
Options Indexes FollowSymLinks
```

`Order`

The **`Order`** directive allows you to specify the order in which the **`Allow`** and **`Deny`** directives are evaluated. It takes the following form:

```
Order option
```

The *`option`* has to be a valid keyword as described in *Table 13.14, "Available Order options"*. The default option is **`allow,deny`**.

Table 13.14. Available Order options

Option	Description
`allow,deny`	**`Allow`** directives are evaluated first.
`deny,allow`	**`Deny`** directives are evaluated first.

Example 13.53. Using the Order directive

```
Order allow,deny
```

`PidFile`

The **`PidFile`** directive allows you to specify a file to which the *process ID* (PID) of the server is stored. It takes the following form:

```
PidFile path
```

The *`path`* refers to a pid file, and can be either absolute, or relative to the directory that is specified by the **`ServerRoot`** directive (that is, **`/etc/httpd/`** by default). The default option is **`run/httpd.pid`**.

Example 13.54. Using the PidFile directive

```
PidFile run/httpd.pid
```

`ProxyRequests`

The **`ProxyRequests`** directive allows you to enable forward proxy requests. It takes the following form:

```
ProxyRequests option
```

The *`option`* has to be a valid keyword as described in *Table 13.15, "Available ProxyRequests options"*. The default option is **`Off`**.

Table 13.15. Available ProxyRequests options

Option	Description
On	Enables forward proxy requests.
Off	Disables forward proxy requests.

Example 13.55. Using the ProxyRequests directive

```
ProxyRequests On
```

ReadmeName

The **ReadmeName** directive allows you to specify a file to be appended to the end of the server-generated directory listing. It takes the following form:

```
ReadmeName filename
```

The *filename* is a name of the file to look for in the requested directory. By default, the server looks for **README.html**.

Example 13.56. Using the ReadmeName directive

```
ReadmeName README.html
```

Redirect

The **Redirect** directive allows you to redirect a client to another URL. It takes the following form:

```
Redirect [status] path url
```

The *status* is optional, and if provided, it has to be a valid keyword as described in *Table 13.16, "Available status options"*. The *path* refers to the old location, and must be relative to the directory specified by the **DocumentRoot** directive (for example, **/docs**). The *url* refers to the current location of the content (for example, **http://docs.example.com**).

Table 13.16. Available status options

Status	Description
permanent	Indicates that the requested resource has been moved permanently. The **301** (Moved Permanently) status code is returned to a client.
temp	Indicates that the requested resource has been moved only temporarily. The **302** (Found) status code is returned to a client.
seeother	Indicates that the requested resource has been replaced. The **303** (See Other) status code is returned to a client.
gone	Indicates that the requested resource has been removed permanently. The **410** (Gone) status is returned to a client.

Note that for more advanced redirection techniques, you can use the `mod_rewrite` module that is part of the Apache HTTP Server installation.

Example 13.57. Using the Redirect directive

```
Redirect permanent /docs http://docs.example.com
```

ScriptAlias

The **ScriptAlias** directive allows you to specify the location of CGI scripts. It takes the following form:

```
ScriptAlias url-path real-path
```

The *url-path* must be relative to the directory specified by the **DocumentRoot** directive (for example, **/cgi-bin/**). The *real-path* is a full path to a file or directory in the local file system.

This directive is typically followed by the **Directory** tag with additional permissions to access the target directory. By default, the **/cgi-bin/** alias is created so that the scripts located in the **/var/www/cgi-bin/** are accessible.

The **ScriptAlias** directive is used for security reasons to prevent CGI scripts from being viewed as ordinary text documents.

Example 13.58. Using the ScriptAlias directive

```
ScriptAlias /cgi-bin/ /var/www/cgi-bin/

<Directory "/var/www/cgi-bin">
  AllowOverride None
  Options None
  Order allow,deny
  Allow from all
</Directory>
```

ServerAdmin

The **ServerAdmin** directive allows you to specify the email address of the server administrator to be displayed in server-generated web pages. It takes the following form:

```
ServerAdmin email
```

The default option is **root@localhost**.

This directive is commonly set to **webmaster@*hostname***, where *hostname* is the address of the server. Once set, alias **webmaster** to the person responsible for the web server in **/etc/aliases**, and as superuser, run the **newaliases** command.

Example 13.59. Using the ServerAdmin directive

```
ServerAdmin webmaster@penguin.example.com
```

ServerName

The **ServerName** directive allows you to specify the hostname and the port number of a web server. It takes the following form:

```
ServerName hostname[:port]
```

The *hostname* has to be a *fully qualified domain name* (FQDN) of the server. The *port* is optional, but when supplied, it has to match the number specified by the **Listen** directive.

When using this directive, make sure that the IP address and server name pair are included in the **/etc/hosts** file.

Example 13.60. Using the ServerName directive

```
ServerName penguin.example.com:80
```

ServerRoot

The **ServerRoot** directive allows you to specify the directory in which the server operates. It takes the following form:

```
ServerRoot directory
```

The *directory* must be a full path to an existing directory in the local file system. The default option is **/etc/httpd/**.

Example 13.61. Using the ServerRoot directive

```
ServerRoot /etc/httpd
```

ServerSignature

The **ServerSignature** directive allows you to enable displaying information about the server on server-generated documents. It takes the following form:

```
ServerSignature option
```

The *option* has to be a valid keyword as described in *Table 13.17, "Available ServerSignature options"*. The default option is **On**.

Table 13.17. Available ServerSignature options

Option	Description
On	Enables appending the server name and version to server-generated pages.
Off	Disables appending the server name and version to server-generated pages.
EMail	Enables appending the server name, version, and the email address of the system administrator as specified by the **ServerAdmin** directive to server-generated pages.

Example 13.62. Using the ServerSignature directive

```
ServerSignature On
```

ServerTokens

The **ServerTokens** directive allows you to customize what information are included in the Server response header. It takes the following form:

```
ServerTokens option
```

The *option* has to be a valid keyword as described in *Table 13.18, "Available ServerTokens options"*. The default option is **OS**.

Table 13.18. Available ServerTokens options

Option	Description
Prod	Includes the product name only (that is, **Apache**).
Major	Includes the product name and the major version of the server (for example, **2**).
Minor	Includes the product name and the minor version of the server (for example, **2.2**).
Min	Includes the product name and the minimal version of the server (for example, **2.2.15**).
OS	Includes the product name, the minimal version of the server, and the type of the operating system it is running on (for example, **Red Hat**).
Full	Includes all the information above along with the list of loaded modules.

Note that for security reasons, it is recommended to reveal as little information about the server as possible.

Example 13.63. Using the ServerTokens directive

```
ServerTokens Prod
```

SuexecUserGroup

The **SuexecUserGroup** directive allows you to specify the user and group under which the CGI scripts will be run. It takes the following form:

```
SuexecUserGroup user group
```

The *user* has to be an existing user, and the *group* must be a valid UNIX group.

For security reasons, the CGI scripts should not be run with `root` privileges. Note that in **<VirtualHost>**, **SuexecUserGroup** replaces the **User** and **Group** directives.

Example 13.64. Using the SuexecUserGroup directive

```
SuexecUserGroup apache apache
```

Timeout

The **Timeout** directive allows you to specify the amount of time to wait for an event before closing a connection. It takes the following form:

```
Timeout time
```

The *time* is specified in seconds. The default option is **60**.

Example 13.65. Using the Timeout directive

```
Timeout 60
```

TypesConfig

The **TypesConfig** allows you to specify the location of the MIME types configuration file. It takes the following form:

```
TypesConfig path
```

The *path* refers to an existing MIME types configuration file, and can be either absolute, or relative to the directory that is specified by the **ServerRoot** directive (that is, **/etc/httpd/** by default). The default option is **/etc/mime.types**.

Note that instead of editing **/etc/mime.types**, the recommended way to add MIME type mapping to the Apache HTTP Server is to use the **AddType** directive.

Example 13.66. Using the TypesConfig directive

```
TypesConfig /etc/mime.types
```

UseCanonicalName

The **UseCanonicalName** allows you to specify the way the server refers to itself. It takes the following form:

```
UseCanonicalName option
```

The *option* has to be a valid keyword as described in *Table 13.19, "Available UseCanonicalName options"*. The default option is **Off**.

Table 13.19. Available UseCanonicalName options

Option	Description
On	Enables the use of the name that is specified by the **ServerName** directive.
Off	Disables the use of the name that is specified by the **ServerName** directive. The hostname and port number provided by the requesting client are used instead.
DNS	Disables the use of the name that is specified by the **ServerName** directive. The hostname determined by a reverse DNS lookup is used instead.

Example 13.67. Using the UseCanonicalName directive

```
UseCanonicalName Off
```

User

The **User** directive allows you to specify the user under which the `httpd` service will run. It takes the following form:

```
User user
```

The *user* has to be an existing UNIX user. The default option is **apache**.

For security reasons, the `httpd` service should not be run with `root` privileges. Note that **User** is no longer supported inside **<VirtualHost>**, and has been replaced by the **SuexecUserGroup** directive.

Example 13.68. Using the User directive

```
User apache
```

UserDir

The **UserDir** directive allows you to enable serving content from users' home directories. It takes the following form:

```
UserDir option
```

The *option* can be either a name of the directory to look for in user's home directory (typically **public_html**), or a valid keyword as described in *Table 13.20, "Available UserDir options"*. The default option is **disabled**.

Table 13.20. Available UserDir options

Option	Description
enabled *user*…	Enables serving content from home directories of given *user*s.
disabled [*user*…]	Disables serving content from home directories, either for all users, or, if a space separated list of *user*s is supplied, for given users only.



Set the correct permissions

In order for the web server to access the content, the permissions on relevant directories and files must be set correctly. Make sure that all users are able to access the home directories, and that they can access and read the content of the directory specified by the **UserDir** directive. For example, to allow access to **public_html/** in the home directory of user `joe`, type the following at a shell prompt as `root`:

```
~]# chmod a+x /home/joe/
~]# chmod a+rx /home/joe/public_html/
```

All files in this directory must be set accordingly.

Example 13.69. Using the UserDir directive

```
UserDir public_html
```

13.1.5.2. Common ssl.conf Directives

The *Secure Sockets Layer* (SSL) directives allow you to customize the behavior of the Apache HTTP Secure Server, and in most cases, they are configured appropriately during the installation. Be careful when changing these settings, as incorrect configuration can lead to security vulnerabilities.

The following directive is commonly used in **/etc/httpd/conf.d/ssl.conf**:

SetEnvIf

The **SetEnvIf** directive allows you to set environment variables based on the headers of incoming connections. It takes the following form:

```
SetEnvIf option pattern [!]variable[=value]…
```

The *option* can be either a HTTP header field, a previously defined environment variable name, or a valid keyword as described in *Table 13.21, "Available SetEnvIf options"*. The *pattern* is a regular expression. The *variable* is an environment variable that is set when the option matches the pattern. If the optional exclamation mark (that is, **!**) is present, the variable is removed instead of being set.

Table 13.21. Available SetEnvIf options

Option	Description
Remote_Host	Refers to the client's hostname.
Remote_Addr	Refers to the client's IP address.
Server_Addr	Refers to the server's IP address.
Request_Method	Refers to the request method (for example, **GET**).
Request_Protocol	Refers to the protocol name and version (for example, **HTTP/1.1**).
Request_URI	Refers to the requested resource.

The **SetEnvIf** directive is used to disable HTTP keepalives, and to allow SSL to close the connection without a closing notification from the client browser. This is necessary for certain web browsers that do not reliably shut down the SSL connection.

Example 13.70. Using the SetEnvIf directive

```
SetEnvIf User-Agent ".*MSIE.*" \
         nokeepalive ssl-unclean-shutdown \
         downgrade-1.0 force-response-1.0
```

Note that for the **/etc/httpd/conf.d/ssl.conf** file to be present, the *mod_ssl* needs to be installed. Refer to *Section 13.1.8, "Setting Up an SSL Server"* for more information on how to install and configure an SSL server.

13.1.5.3. Common Multi-Processing Module Directives

The *Multi-Processing Module* (MPM) directives allow you to customize the behavior of a particular MPM specific server-pool. Since its characteristics differ depending on which MPM is used, the directives are embedded in **`IfModule`**. By default, the server-pool is defined for both the `prefork` and `worker` MPMs.

The following MPM directives are commonly used in **`/etc/httpd/conf/httpd.conf`**:

`MaxClients`

The **`MaxClients`** directive allows you to specify the maximum number of simultaneously connected clients to process at one time. It takes the following form:

```
MaxClients number
```

A high *`number`* can improve the performance of the server, although it is not recommended to exceed **`256`** when using the `prefork` MPM.

Example 13.71. Using the MaxClients directive

```
MaxClients 256
```

`MaxRequestsPerChild`

The **`MaxRequestsPerChild`** directive allows you to specify the maximum number of request a child process can serve before it dies. It takes the following form:

```
MaxRequestsPerChild number
```

Setting the *`number`* to **`0`** allows unlimited number of requests.

The **`MaxRequestsPerChild`** directive is used to prevent long-lived processes from causing memory leaks.

Example 13.72. Using the MaxRequestsPerChild directive

```
MaxRequestsPerChild 4000
```

`MaxSpareServers`

The **`MaxSpareServers`** directive allows you to specify the maximum number of spare child processes. It takes the following form:

```
MaxSpareServers number
```

This directive is used by the `prefork` MPM only.

Example 13.73. Using the MaxSpareServers directive

```
MaxSpareServers 20
```

MaxSpareThreads

The **MaxSpareThreads** directive allows you to specify the maximum number of spare server threads. It takes the following form:

```
MaxSpareThreads number
```

The *number* must be greater than or equal to the sum of **MinSpareThreads** and **ThreadsPerChild**. This directive is used by the `worker` MPM only.

Example 13.74. Using the MaxSpareThreads directive

```
MaxSpareThreads 75
```

MinSpareServers

The **MinSpareServers** directive allows you to specify the minimum number of spare child processes. It takes the following form:

```
MinSpareServers number
```

Note that a high *number* can create a heavy processing load on the server. This directive is used by the `prefork` MPM only.

Example 13.75. Using the MinSpareServers directive

```
MinSpareServers 5
```

MinSpareThreads

The **MinSpareThreads** directive allows you to specify the minimum number of spare server threads. It takes the following form:

```
MinSpareThreads number
```

This directive is used by the `worker` MPM only.

Example 13.76. Using the MinSpareThreads directive

```
MinSpareThreads 75
```

StartServers

The **StartServers** directive allows you to specify the number of child processes to create when the service is started. It takes the following form:

```
StartServers number
```

Since the child processes are dynamically created and terminated according to the current traffic load, it is usually not necessary to change this value.

Example 13.77. Using the StartServers directive

```
StartServers 8
```

ThreadsPerChild

The **ThreadsPerChild** directive allows you to specify the number of threads a child process can create. It takes the following form:

```
ThreadsPerChild number
```

This directive is used by the `worker` MPM only.

Example 13.78. Using the ThreadsPerChild directive

```
ThreadsPerChild 25
```

13.1.6. Working with Modules

Being a modular application, the `httpd` service is distributed along with a number of *Dynamic Shared Objects* (DSOs), which can be dynamically loaded or unloaded at runtime as necessary. By default, these modules are located in **/usr/lib/httpd/modules/** on 32-bit and in **/usr/lib64/httpd/modules/** on 64-bit systems.

13.1.6.1. Loading a Module

To load a particular DSO module, use the **LoadModule** directive as described in *Section 13.1.5.1, "Common httpd.conf Directives"*. Note that modules provided by a separate package often have their own configuration file in the **/etc/httpd/conf.d/** directory.

Example 13.79. Loading the mod_ssl DSO

```
LoadModule ssl_module modules/mod_ssl.so
```

Once you are finished, restart the web server to reload the configuration. Refer to *Section 13.1.4.3, "Restarting the Service"* for more information on how to restart the `httpd` service.

13.1.6.2. Writing a Module

If you intend to create a new DSO module, make sure you have the *httpd-devel* package installed. To do so, type the following at a shell prompt as `root`:

```
yum install httpd-devel
```

This package contains the include files, the header files, and the **APache eXtenSion** (**apxs**) utility required to compile a module.

Once written, you can build the module with the following command:

```
apxs -i -a -c module_name.c
```

If the build was successful, you should be able to load the module the same way as any other module that is distributed with the Apache HTTP Server.

13.1.7. Setting Up Virtual Hosts

The Apache HTTP Server's built in virtual hosting allows the server to provide different information based on which IP address, hostname, or port is being requested.

To create a name-based virtual host, find the virtual host container provided in **`/etc/httpd/conf/httpd.conf`** as an example, remove the hash sign (that is, **#**) from the beginning of each line, and customize the options according to your requirements as shown in *Example 13.80, "Sample virtual host configuration"*.

Example 13.80. Sample virtual host configuration

```
NameVirtualHost penguin.example.com:80

<VirtualHost penguin.example.com:80>
    ServerAdmin webmaster@penguin.example.com
    DocumentRoot /www/docs/penguin.example.com
    ServerName penguin.example.com:80
    ErrorLog logs/penguin.example.com-error_log
    CustomLog logs/penguin.example.com-access_log common
</VirtualHost>
```

Note that **`ServerName`** must be a valid DNS name assigned to the machine. The **`<VirtualHost>`** container is highly customizable, and accepts most of the directives available within the main server configuration. Directives that are *not* supported within this container include **`User`** and **`Group`**, which were replaced by **`SuexecUserGroup`**.



Changing the port number

If you configure a virtual host to listen on a non-default port, make sure you update the **`Listen`** directive in the global settings section of the **`/etc/httpd/conf/httpd.conf`** file accordingly.

To activate a newly created virtual host, the web server has to be restarted first. Refer to *Section 13.1.4.3, "Restarting the Service"* for more information on how to restart the `httpd` service.

13.1.8. Setting Up an SSL Server

Secure Sockets Layer (SSL) is a cryptographic protocol that allows a server and a client to communicate securely. Along with its extended and improved version called *Transport Layer Security* (TLS), it ensures both privacy and data integrity. The Apache HTTP Server in combination with `mod_ssl`, a module that uses the OpenSSL toolkit to provide the SSL/TLS support, is commonly referred to as the *SSL server*.

Unlike a regular HTTP connection that can be read and possibly modified by anybody who is able to intercept it, the use of `mod_ssl` prevents any inspection or modification of the transmitted content.

This section provides basic information on how to enable this module in the Apache HTTP Server configuration, and guides you through the process of generating private keys and self-signed certificates.

13.1.8.1. An Overview of Certificates and Security

Secure communication is based on the use of keys. In conventional or *symmetric cryptography*, both ends of the transaction have the same key they can use to decode each other's transmissions. On the other hand, in public or *asymmetric cryptography*, two keys co-exist: a *private key* that is kept a secret, and a *public key* that is usually shared with the public. While the data encoded with the public key can only be decoded with the private key, data encoded with the private key can in turn only be decoded with the public key.

To provide secure communications using SSL, an SSL server must use a digital certificate signed by a *Certificate Authority* (CA). The certificate lists various attributes of the server (that is, the server hostname, the name of the company, its location, etc.), and the signature produced using the CA's private key. This signature ensures that a particular certificate authority has issued the certificate, and that the certificate has not been modified in any way.

When a web browser establishes a new SSL connection, it checks the certificate provided by the web server. If the certificate does not have a signature from a trusted CA, or if the hostname listed in the certificate does not match the hostname used to establish the connection, it refuses to communicate with the server and usually presents a user with an appropriate error message.

By default, most web browsers are configured to trust a set of widely used certificate authorities. Because of this, an appropriate CA should be chosen when setting up a secure server, so that target users can trust the connection, otherwise they will be presented with an error message, and will have to accept the certificate manually. Since encouraging users to override certificate errors can allow an attacker to intercept the connection, you should use a trusted CA whenever possible. For more information on this, see *Table 13.22, "CA lists for most common web browsers"*.

Table 13.22. CA lists for most common web browsers

Web Browser	Link
Mozilla Firefox	*Mozilla root CA list*[2].
Opera	*The Opera Rootstore*[3].
Internet Explorer	*Windows root certificate program members*[4].

When setting up an SSL server, you need to generate a certificate request and a private key, and then send the certificate request, proof of the company's identity, and payment to a certificate authority. Once the CA verifies the certificate request and your identity, it will send you a signed certificate you can use with your server. Alternatively, you can create a self-signed certificate that does not contain a CA signature, and thus should be used for testing purposes only.

13.1.8.2. Enabling the mod_ssl Module

If you intend to set up an SSL server, make sure you have the *mod_ssl* (the `mod_ssl` module) and *openssl* (the OpenSSL toolkit) packages installed. To do so, type the following at a shell prompt as `root`:

[2] http://www.mozilla.org/projects/security/certs/included/
[3] http://my.opera.com/rootstore/blog/
[4] http://support.microsoft.com/kb/931125

```
yum install mod_ssl openssl
```

This will create the `mod_ssl` configuration file at **`/etc/httpd/conf.d/ssl.conf`**, which is included in the main Apache HTTP Server configuration file by default. For the module to be loaded, restart the `httpd` service as described in *Section 13.1.4.3, "Restarting the Service"*.

13.1.8.3. Using an Existing Key and Certificate

If you have a previously created key and certificate, you can configure the SSL server to use these files instead of generating new ones. There are only two situations where this is not possible:

1. *You are changing the IP address or domain name.*

   Certificates are issued for a particular IP address and domain name pair. If one of these values changes, the certificate becomes invalid.

2. *You have a certificate from VeriSign, and you are changing the server software.*

   VeriSign, a widely used certificate authority, issues certificates for a particular software product, IP address, and domain name. Changing the software product renders the certificate invalid.

In either of the above cases, you will need to obtain a new certificate. For more information on this topic, refer to *Section 13.1.8.4, "Generating a New Key and Certificate"*.

If you wish to use an existing key and certificate, move the relevant files to the **`/etc/pki/tls/private/`** and **`/etc/pki/tls/certs/`** directories respectively. You can do so by running the following commands as `root`:

```
mv key_file.key /etc/pki/tls/private/hostname.key
mv certificate.crt /etc/pki/tls/certs/hostname.crt
```

Then add the following lines to the **`/etc/httpd/conf.d/ssl.conf`** configuration file:

```
SSLCertificateFile /etc/pki/tls/certs/hostname.crt
SSLCertificateKeyFile /etc/pki/tls/private/hostname.key
```

To load the updated configuration, restart the `httpd` service as described in *Section 13.1.4.3, "Restarting the Service"*.

Example 13.81. Using a key and certificate from the Red Hat Secure Web Server

```
~]# mv /etc/httpd/conf/httpsd.key /etc/pki/tls/private/penguin.example.com.key
~]# mv /etc/httpd/conf/httpsd.crt /etc/pki/tls/certs/penguin.example.com.crt
```

13.1.8.4. Generating a New Key and Certificate

In order to generate a new key and certificate pair, you must to have the *crypto-utils* package installed in your system. As `root`, you can install it by typing the following at a shell prompt:

```
yum install crypto-utils
```

This package provides a set of tools to generate and manage SSL certificates and private keys, and includes **genkey**, the Red Hat Keypair Generation utility that will guide you through the key generation process.



Replacing an existing certificate

If the server already has a valid certificate and you are replacing it with a new one, specify a different serial number. This ensures that client browsers are notified of this change, update to this new certificate as expected, and do not fail to access the page. To create a new certificate with a custom serial number, as `root`, use the following command instead of **genkey**:

```
openssl req -x509 -new -set_serial number -key hostname.key -out hostname.crt
```



Remove a previously created key

If there already is a key file for a particular hostname in your system, **genkey** will refuse to start. In this case, remove the existing file using the following command as `root`:

```
rm /etc/pki/tls/private/hostname.key
```

To run the utility, as `root`, run the **genkey** command followed by the appropriate hostname (for example, `penguin.example.com`):

```
genkey hostname
```

To complete the key and certificate creation, take the following steps:

1. Review the target locations in which the key and certificate will be stored.

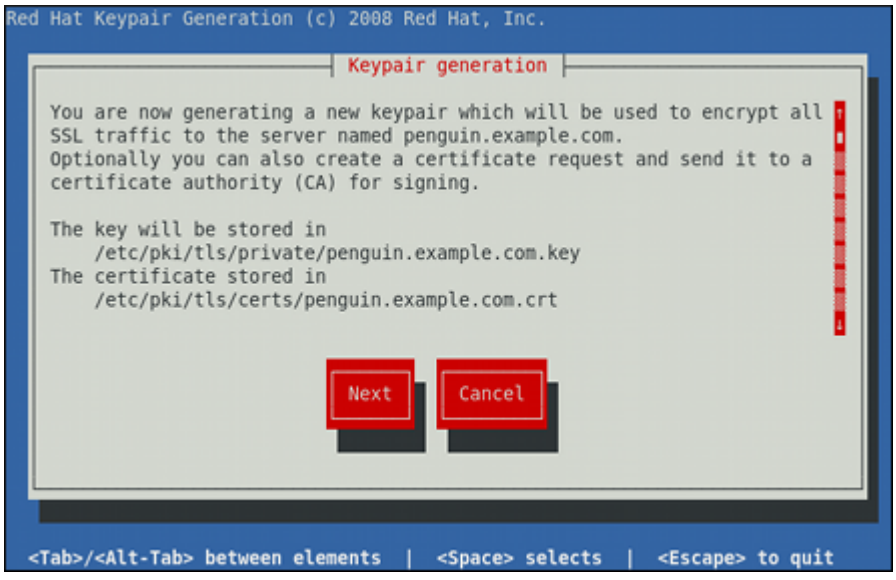


Figure 13.1. Running the genkey utility

Use the **Tab** key to select the **Next** button, and press **Enter** to proceed to the next screen.

2. Using the **Up** and **down** arrow keys, select the suitable key size. Note that while the large key increases the security, it also increases the response time of your server. Because of this, the recommended option is **1024 bits**.

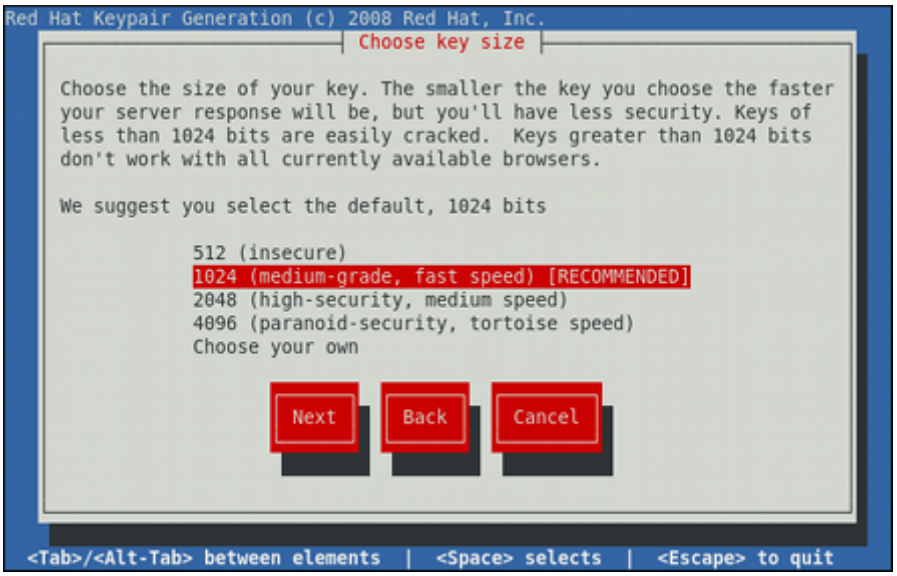


Figure 13.2. Selecting the key size

Once finished, use the **Tab** key to select the **Next** button, and press **Enter** to initiate the random bits generation process. Depending on the selected key size, this may take some time.

3. Decide whether you wish to send a certificate request to a certificate authority.



Figure 13.3. Generating a certificate request

Use the **Tab** key to select **Yes** to compose a certificate request, or **No** to generate a self-signed certificate. Then press **Enter** to confirm your choice.

4. Using the **Spacebar** key, enable (**[*]**) or disable (**[ ]**) the encryption of the private key.



Figure 13.4. Encrypting the private key

Use the **Tab** key to select the **Next** button, and press **Enter** to proceed to the next screen.

5. If you have enabled the private key encryption, enter an adequate passphrase. Note that for security reasons, it is not displayed as you type, and it must be at least five characters long.

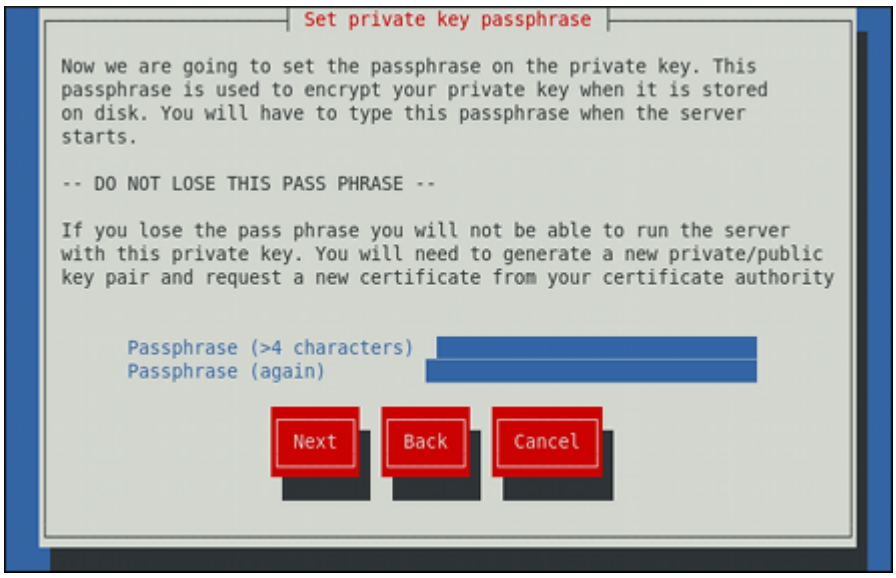


Figure 13.5. Entering a passphrase

Use the **Tab** key to select the **Next** button, and press **Enter** to proceed to the next screen.



Do not forget the passphrase

Entering the correct passphrase is required in order for the server to start. If you lose it, you will need to generate a new key and certificate.

6. Customize the certificate details.

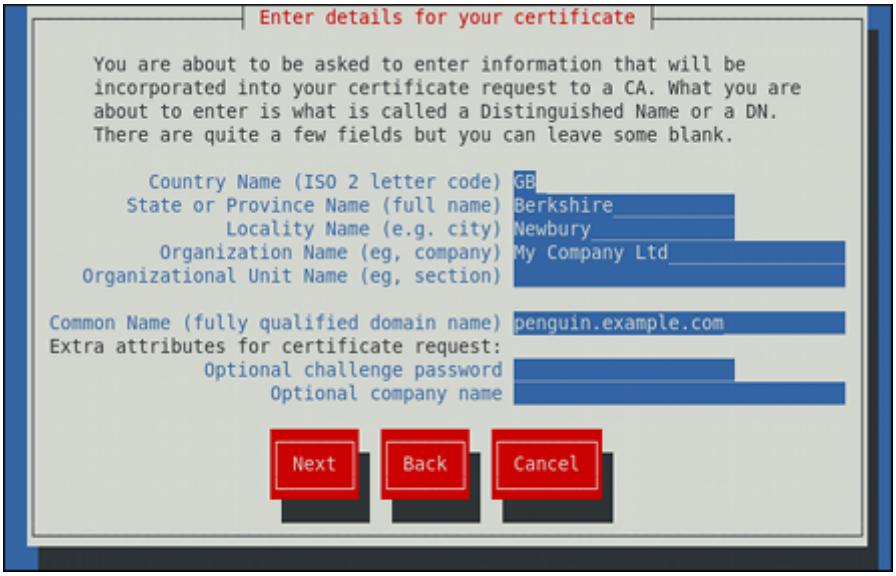


Figure 13.6. Specifying certificate information

Use the **Tab** key to select the **Next** button, and press **Enter** to finish the key generation.

7. If you have previously enabled the certificate request generation, you will be prompted to send it to a certificate authority.

```
You now need to submit your CSR and documentation to your certificate
authority. Submitting your CSR may involve pasting it into an online
web form, or mailing it to a specific address. In either case, you
should include the BEGIN and END lines.

-----BEGIN NEW CERTIFICATE REQUEST-----
MIIBqjCCARMCAQAwajELMAkGA1UEBhMCR0IxEjAQBgNVBAgTCUJlcmtzaGlyZTEQ
MA4GA1UEBxMHTmV3YnVyeTEXMBUGA1UEChMOTXkgQ29tcGFueSBMdGQxHDAaBgNV
BAMTE3Blbmd1aW4uZXhhbXBsZS5jb20wgZ8wDQYJKoZIhvcNAQEBBQADgY0AMIGJ
AoGBAJjw8bXq7WKGGXNZsNZltEe9849wUMc4uAh+X8251b8x+ptJQCanGeNhLlXU
xiL5srY2TjoTSQ5DvyFgPQmFFe3cn7v//bKNgNqd4h0EbRFGaj/hDUG3fXnjujkX
hP+9iY/eIAQZlHQSkABh/2egtIllpfDeRvsTUX376TnkIWLhAgMBAAGgADANBgkq
hkiG9w0BAQQFAAOBgQBUTjgjcnts1hZKO70c5j+b4IfsBCwm4lnvGx3jOwpLdRq/
rHpx5cbHV99vcKnF3CwDrze9DgpTdjdbAccSCVgSG5GE8JZXWYD8EK8p2naJNQl1
YVX1KPi5MPLZuZ9cTb+k4K0cbug0IQiYaKNLNI/0zLE1VEWZXYFXOUBFM2gXYw==
-----END NEW CERTIFICATE REQUEST-----


A copy of this CSR has been saved in the file
/etc/pki/tls/certs/penguin.example.com.1.csr

Press return when ready to continue
```

Figure 13.7. Instructions on how to send a certificate request

Press **Enter** to return to a shell prompt.

Once generated, add the key and certificate locations to the **/etc/httpd/conf.d/ssl.conf** configuration file:

```
SSLCertificateFile /etc/pki/tls/certs/hostname.crt
SSLCertificateKeyFile /etc/pki/tls/private/hostname.key
```

Finally, restart the `httpd` service as described in *Section 13.1.4.3, "Restarting the Service"*, so that the updated configuration is loaded.

13.1.9. Additional Resources

To learn more about the Apache HTTP Server, refer to the following resources.

13.1.9.1. Installed Documentation

http://localhost/manual/
: The official documentation for the Apache HTTP Server with the full description of its directives and available modules. Note that in order to access this documentation, you must have the *httpd-manual* package installed, and the web server must be running.

`man httpd`
: The manual page for the `httpd` service containing the complete list of its command line options.

`man genkey`
: The manual page for **genkey** containing the full documentation on its usage.

13.1.9.2. Useful Websites

http://httpd.apache.org/
: The official website for the Apache HTTP Server with documentation on all the directives and default modules.

http://www.modssl.org/
: The official website for the **mod_ssl** module.

http://www.openssl.org/
: The OpenSSL home page containing further documentation, frequently asked questions, links to the mailing lists, and other useful resources.

Mail Servers

Email was born in the 1960s. The mailbox was a file in a user's home directory that was readable only by that user. Primitive mail applications appended new text messages to the bottom of the file, making the user wade through the constantly growing file to find any particular message. This system was only capable of sending messages to users on the same system.

The first network transfer of an electronic mail message file took place in 1971 when a computer engineer named Ray Tomlinson sent a test message between two machines via ARPANET—the precursor to the Internet. Communication via email soon became very popular, comprising 75 percent of ARPANET's traffic in less than two years.

Today, email systems based on standardized network protocols have evolved into some of the most widely used services on the Internet. Fedora offers many advanced applications to serve and access email.

This chapter reviews modern email protocols in use today, and some of the programs designed to send and receive email.

14.1. Email Protocols

Today, email is delivered using a client/server architecture. An email message is created using a mail client program. This program then sends the message to a server. The server then forwards the message to the recipient's email server, where the message is then supplied to the recipient's email client.

To enable this process, a variety of standard network protocols allow different machines, often running different operating systems and using different email programs, to send and receive email.

The following protocols discussed are the most commonly used in the transfer of email.

14.1.1. Mail Transport Protocols

Mail delivery from a client application to the server, and from an originating server to the destination server, is handled by the *Simple Mail Transfer Protocol* (*SMTP*).

14.1.1.1. SMTP

The primary purpose of SMTP is to transfer email between mail servers. However, it is critical for email clients as well. To send email, the client sends the message to an outgoing mail server, which in turn contacts the destination mail server for delivery. For this reason, it is necessary to specify an SMTP server when configuring an email client.

Under Fedora, a user can configure an SMTP server on the local machine to handle mail delivery. However, it is also possible to configure remote SMTP servers for outgoing mail.

One important point to make about the SMTP protocol is that it does not require authentication. This allows anyone on the Internet to send email to anyone else or even to large groups of people. It is this characteristic of SMTP that makes junk email or *spam* possible. Imposing relay restrictions limits random users on the Internet from sending email through your SMTP server, to other servers on the internet. Servers that do not impose such restrictions are called *open relay* servers.

Fedora provides the Postfix and Sendmail SMTP programs.

14.1.2. Mail Access Protocols

There are two primary protocols used by email client applications to retrieve email from mail servers: the *Post Office Protocol* (*POP*) and the *Internet Message Access Protocol* (*IMAP*).

14.1.2.1. POP

The default POP server under Fedora is **Dovecot** and is provided by the *dovecot* package.



Installing the dovecot package

In order to use **Dovecot**, first ensure the **dovecot** package is installed on your system by running, as `root`:

```
yum install dovecot
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

When using a POP server, email messages are downloaded by email client applications. By default, most POP email clients are automatically configured to delete the message on the email server after it has been successfully transferred, however this setting usually can be changed.

POP is fully compatible with important Internet messaging standards, such as *Multipurpose Internet Mail Extensions* (*MIME*), which allow for email attachments.

POP works best for users who have one system on which to read email. It also works well for users who do not have a persistent connection to the Internet or the network containing the mail server. Unfortunately for those with slow network connections, POP requires client programs upon authentication to download the entire content of each message. This can take a long time if any messages have large attachments.

The most current version of the standard POP protocol is POP3.

There are, however, a variety of lesser-used POP protocol variants:

- *APOP* — POP3 with MDS (Monash Directory Service) authentication. An encoded hash of the user's password is sent from the email client to the server rather then sending an unencrypted password.
- *KPOP* — POP3 with Kerberos authentication.
- *RPOP* — POP3 with RPOP authentication. This uses a per-user ID, similar to a password, to authenticate POP requests. However, this ID is not encrypted, so RPOP is no more secure than standard POP.

For added security, it is possible to use *Secure Socket Layer* (*SSL*) encryption for client authentication and data transfer sessions. This can be enabled by using the **pop3s** service, or by using the **/usr/sbin/stunnel** application. For more information on securing email communication, refer to *Section 14.5.1, "Securing Communication"*.

14.1.2.2. IMAP

The default IMAP server under Fedora is **Dovecot** and is provided by the *dovecot* package. Refer to *Section 14.1.2.1, "POP"* for information on how to install **Dovecot**.

When using an IMAP mail server, email messages remain on the server where users can read or delete them. IMAP also allows client applications to create, rename, or delete mail directories on the server to organize and store email.

IMAP is particularly useful for users who access their email using multiple machines. The protocol is also convenient for users connecting to the mail server via a slow connection, because only the email header information is downloaded for messages until opened, saving bandwidth. The user also has the ability to delete messages without viewing or downloading them.

For convenience, IMAP client applications are capable of caching copies of messages locally, so the user can browse previously read messages when not directly connected to the IMAP server.

IMAP, like POP, is fully compatible with important Internet messaging standards, such as MIME, which allow for email attachments.

For added security, it is possible to use SSL encryption for client authentication and data transfer sessions. This can be enabled by using the **imaps** service, or by using the **/usr/sbin/stunnel** program. For more information on securing email communication, refer to *Section 14.5.1, "Securing Communication"*.

Other free, as well as commercial, IMAP clients and servers are available, many of which extend the IMAP protocol and provide additional functionality.

14.1.2.3. Dovecot

The **imap-login** and **pop3-login** processes which implement the IMAP and POP3 protocols are spawned by the master dovecot daemon included in the *dovecot* package. The use of IMAP and POP is configured through the **/etc/dovecot/dovecot.conf** configuration file; by default **dovecot** runs IMAP and POP3 together with their secure versions using SSL. To configure **dovecot** to use POP, complete the following steps:

1. Edit the **/etc/dovecot/dovecot.conf** configuration file to make sure the **protocols** variable is uncommented (remove the hash sign (#) at the beginning of the line) and contains the **pop3** argument. For example:

   ```
   protocols = imap imaps pop3 pop3s
   ```

   When the **protocols** variable is left commented out, **dovecot** will use the default values specified for this variable.

2. Make that change operational for the current session by running the following command as root:

   ```
   systemctl restart dovecot.service
   ```

3. Make that change operational after the next reboot by running the command:

   ```
   systemctl enable dovecot.service
   ```



The dovecot service starts the POP3 server

Please note that **dovecot** only reports that it started the IMAP server, but also starts the POP3 server.

Unlike SMTP, both IMAP and POP3 require connecting clients to authenticate using a username and password. By default, passwords for both protocols are passed over the network unencrypted.

To configure SSL on **dovecot**:

- Edit the **/etc/pki/dovecot/dovecot-openssl.conf** configuration file as you prefer. However, in a typical installation, this file does not require modification.
- Rename, move or delete the files **/etc/pki/dovecot/certs/dovecot.pem** and **/etc/pki/dovecot/private/dovecot.pem**.
- Execute the **/usr/libexec/dovecot/mkcert.sh** script which creates the **dovecot** self signed certificates. These certificates are copied in the **/etc/pki/dovecot/certs** and **/etc/pki/dovecot/private** directories. To implement the changes, restart **dovecot** by typing the following at a shell prompt as root:

```
systemctl restart dovecot.service
```

More details on **dovecot** can be found online at *http://www.dovecot.org*.

14.2. Email Program Classifications

In general, all email applications fall into at least one of three classifications. Each classification plays a specific role in the process of moving and managing email messages. While most users are only aware of the specific email program they use to receive and send messages, each one is important for ensuring that email arrives at the correct destination.

14.2.1. Mail Transport Agent

A *Mail Transport Agent* (*MTA*) transports email messages between hosts using SMTP. A message may involve several MTAs as it moves to its intended destination.

While the delivery of messages between machines may seem rather straightforward, the entire process of deciding if a particular MTA can or should accept a message for delivery is quite complicated. In addition, due to problems from spam, use of a particular MTA is usually restricted by the MTA's configuration or the access configuration for the network on which the MTA resides.

Many modern email client programs can act as an MTA when sending email. However, this action should not be confused with the role of a true MTA. The sole reason email client programs are capable of sending email like an MTA is because the host running the application does not have its own MTA. This is particularly true for email client programs on non-UNIX-based operating systems. However, these client programs only send outbound messages to an MTA they are authorized to use and do not directly deliver the message to the intended recipient's email server.

Since Fedora offers two MTAs—*Postfix* and *Sendmail*—email client programs are often not required to act as an MTA. Fedora also includes a special purpose MTA called *Fetchmail*.

For more information on Postfix, Sendmail, and Fetchmail, refer to *Section 14.3, "Mail Transport Agents"*.

14.2.2. Mail Delivery Agent

A *Mail Delivery Agent* (*MDA*) is invoked by the MTA to file incoming email in the proper user's mailbox. In many cases, the MDA is actually a *Local Delivery Agent* (*LDA*), such as **`mail`** or Procmail.

Any program that actually handles a message for delivery to the point where it can be read by an email client application can be considered an MDA. For this reason, some MTAs (such as Sendmail and Postfix) can fill the role of an MDA when they append new email messages to a local user's mail spool file. In general, MDAs do not transport messages between systems nor do they provide a user interface; MDAs distribute and sort messages on the local machine for an email client application to access.

14.2.3. Mail User Agent

A *Mail User Agent* (*MUA*) is synonymous with an email client application. An MUA is a program that, at the very least, allows a user to read and compose email messages. Many MUAs are capable of retrieving messages via the `POP` or `IMAP` protocols, setting up mailboxes to store messages, and sending outbound messages to an MTA.

MUAs may be graphical, such as **Evolution**, or have simple text-based interfaces, such as **pine**.

14.3. Mail Transport Agents

Fedora offers two primary MTAs: Postfix and Sendmail. Postfix is configured as the default MTA, although it is easy to switch the default MTA to Sendmail. To switch the default MTA to Sendmail, as `root`, you can either uninstall Postfix or use the following command to switch to Sendmail:

```
alternatives --config mta
```

You can also use the following command to enable/disable the desired service:

```
systemctl enable|disable service.service
```

14.3.1. Postfix

Originally developed at IBM by security expert and programmer Wietse Venema, Postfix is a Sendmail-compatible MTA that is designed to be secure, fast, and easy to configure.

To improve security, Postfix uses a modular design, where small processes with limited privileges are launched by a *master* daemon. The smaller, less privileged processes perform very specific tasks related to the various stages of mail delivery and run in a change rooted environment to limit the effects of attacks.

Configuring Postfix to accept network connections from hosts other than the local computer takes only a few minor changes in its configuration file. Yet for those with more complex needs, Postfix provides

a variety of configuration options, as well as third party add-ons that make it a very versatile and full-featured MTA.

The configuration files for Postfix are human readable and support upward of 250 directives. Unlike Sendmail, no macro processing is required for changes to take effect and the majority of the most commonly used options are described in the heavily commented files.

14.3.1.1. The Default Postfix Installation

The Postfix executable is **/usr/sbin/postfix**. This daemon launches all related processes needed to handle mail delivery.

Postfix stores its configuration files in the **/etc/postfix/** directory. The following is a list of the more commonly used files:

- **access** — Used for access control, this file specifies which hosts are allowed to connect to Postfix.
- **main.cf** — The global Postfix configuration file. The majority of configuration options are specified in this file.
- **master.cf** — Specifies how Postfix interacts with various processes to accomplish mail delivery.
- **transport** — Maps email addresses to relay hosts.

The **aliases** file can be found in the **/etc/** directory. This file is shared between Postfix and Sendmail. It is a configurable list required by the mail protocol that describes user ID aliases.



Configuring Postfix as a server for other clients

The default **/etc/postfix/main.cf** file does not allow Postfix to accept network connections from a host other than the local computer. For instructions on configuring Postfix as a server for other clients, refer to *Section 14.3.1.2, "Basic Postfix Configuration"*.

Restart the `postfix` service after changing any options in the configuration files under the **/etc/postfix** directory in order for those changes to take effect. To do so, run the following command as `root`:

```
systemctl restart postfix.service
```

14.3.1.2. Basic Postfix Configuration

By default, Postfix does not accept network connections from any host other than the local host. Perform the following steps as `root` to enable mail delivery for other hosts on the network:

- Edit the **/etc/postfix/main.cf** file with a text editor, such as **vi**.
- Uncomment the **mydomain** line by removing the hash sign (**#**), and replace *domain.tld* with the domain the mail server is servicing, such as **example.com**.
- Uncomment the **myorigin = $mydomain** line.
- Uncomment the **myhostname** line, and replace *host.domain.tld* with the hostname for the machine.

- Uncomment the **mydestination = $myhostname, localhost.$mydomain** line.
- Uncomment the **mynetworks** line, and replace *168.100.189.0/28* with a valid network setting for hosts that can connect to the server.
- Uncomment the **inet_interfaces = all** line.
- Comment the **inet_interfaces = localhost** line.
- Restart the **postfix** service.

Once these steps are complete, the host accepts outside emails for delivery.

Postfix has a large assortment of configuration options. One of the best ways to learn how to configure Postfix is to read the comments within the **/etc/postfix/main.cf** configuration file. Additional resources including information about Postfix configuration, SpamAssassin integration, or detailed descriptions of the **/etc/postfix/main.cf** parameters are available online at *http://www.postfix.org/*.

14.3.1.3. Using Postfix with LDAP

Postfix can use an LDAP directory as a source for various lookup tables (e.g.: **aliases**, **virtual**, **canonical**, etc.). This allows LDAP to store hierarchical user information and Postfix to only be given the result of LDAP queries when needed. By not storing this information locally, administrators can easily maintain it.

14.3.1.3.1. The /etc/aliases lookup example

The following is a basic example for using LDAP to look up the **/etc/aliases** file. Make sure your **/etc/postfix/main.cf** contains the following:

```
alias_maps = hash:/etc/aliases, ldap:/etc/postfix/ldap-aliases.cf
```

Create a **/etc/postfix/ldap-aliases.cf** file if you do not have one created already and make sure it contains the following:

```
server_host = ldap.example.com
search_base = dc=example, dc=com
```

where *ldap.example.com*, *example*, and *com* are parameters that need to be replaced with specification of an existing available LDAP server.



The /etc/postfix/ldap-aliases.cf file

The **/etc/postfix/ldap-aliases.cf** file can specify various parameters, including parameters that enable LDAP SSL and STARTTLS. For more information, refer to the **ldap_table(5)** man page.

For more information on LDAP, refer to *Section 15.1, "OpenLDAP"*.

14.3.2. Sendmail

Sendmail's core purpose, like other MTAs, is to safely transfer email among hosts, usually using the SMTP protocol. However, Sendmail is highly configurable, allowing control over almost every aspect of how email is handled, including the protocol used. Many system administrators elect to use Sendmail as their MTA due to its power and scalability.

14.3.2.1. Purpose and Limitations

It is important to be aware of what Sendmail is and what it can do, as opposed to what it is not. In these days of monolithic applications that fulfill multiple roles, Sendmail may seem like the only application needed to run an email server within an organization. Technically, this is true, as Sendmail can spool mail to each users' directory and deliver outbound mail for users. However, most users actually require much more than simple email delivery. Users usually want to interact with their email using an MUA, that uses POP or IMAP, to download their messages to their local machine. Or, they may prefer a Web interface to gain access to their mailbox. These other applications can work in conjunction with Sendmail, but they actually exist for different reasons and can operate separately from one another.

It is beyond the scope of this section to go into all that Sendmail should or could be configured to do. With literally hundreds of different options and rule sets, entire volumes have been dedicated to helping explain everything that can be done and how to fix things that go wrong. Refer to the *Section 14.6, "Additional Resources"* for a list of Sendmail resources.

This section reviews the files installed with Sendmail by default and reviews basic configuration changes, including how to stop unwanted email (spam) and how to extend Sendmail with the *Lightweight Directory Access Protocol (LDAP)*.

14.3.2.2. The Default Sendmail Installation

In order to use Sendmail, first ensure the *sendmail* package is installed on your system by running, as root:

```
yum install sendmail
```

In order to configure Sendmail, ensure the *sendmail-cf* package is installed on your system by running, as root:

```
yum install sendmail-cf
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

Before using Sendmail, the default MTA has to be switched from Postfix. For more information how to switch the default MTA refer to *Section 14.3, "Mail Transport Agents"*.

The Sendmail executable is **/usr/sbin/sendmail**.

Sendmail's lengthy and detailed configuration file is **/etc/mail/sendmail.cf**. Avoid editing the **sendmail.cf** file directly. To make configuration changes to Sendmail, edit the **/etc/mail/sendmail.mc** file, back up the original **/etc/mail/sendmail.cf**, and use the following alternatives to generate a new configuration file:

- Use the included makefile in **/etc/mail/** (**~]# make all -C /etc/mail/**) to create a new **/etc/mail/sendmail.cf** configuration file. All other generated files in **/etc/mail** (db files) will

be regenerated if needed. The old makemap commands are still usable. The make command will automatically be used by **`systemctl start|restart|reload sendmail.service`**.

- Alternatively you may use the **`m4`** macro processor to create a new **`/etc/mail/sendmail.cf`**. The **`m4`** macro processor is not installed by default. Before using it to create **`/etc/mail/sendmail.cf`**, install the *m4* package as `root`:

```
yum install m4
```

More information on configuring Sendmail can be found in *Section 14.3.2.3, "Common Sendmail Configuration Changes"*.

Various Sendmail configuration files are installed in the **`/etc/mail/`** directory including:

- **`access`** — Specifies which systems can use Sendmail for outbound email.
- **`domaintable`** — Specifies domain name mapping.
- **`local-host-names`** — Specifies aliases for the host.
- **`mailertable`** — Specifies instructions that override routing for particular domains.
- **`virtusertable`** — Specifies a domain-specific form of aliasing, allowing multiple virtual domains to be hosted on one machine.

Several of the configuration files in **`/etc/mail/`**, such as **`access`**, **`domaintable`**, **`mailertable`** and **`virtusertable`**, must actually store their information in database files before Sendmail can use any configuration changes. To include any changes made to these configurations in their database files, run the following command, as `root`:

```
makemap hash /etc/mail/name < /etc/mail/name
```

where *name* represents the name of the configuration file to be updated. You may also restart the `sendmail` service for the changes to take effect by running:

```
systemctl restart sendmail.service
```

For example, to have all emails addressed to the **`example.com`** domain delivered to *`bob@other-example.com`* , add the following line to the **`virtusertable`** file:

```
@example.com bob@other-example.com
```

To finalize the change, the **`virtusertable.db`** file must be updated:

```
makemap hash /etc/mail/virtusertable < /etc/mail/virtusertable
```

Sendmail will create an updated **`virtusertable.db`** file containing the new configuration.

14.3.2.3. Common Sendmail Configuration Changes

When altering the Sendmail configuration file, it is best not to edit an existing file, but to generate an entirely new **`/etc/mail/sendmail.cf`** file.



Backup the sendmail.cf file before changing its content

Before changing the **sendmail.cf** file, it is a good idea to create a backup copy.

To add the desired functionality to Sendmail, edit the **/etc/mail/sendmail.mc** file as `root`. Once you are finished, restart the `sendmail` service and, if the *m4* package is installed, the **m4** macro processor will automatically generate a new **sendmail.cf** configuration file:

```
systemctl restart sendmail.service
```



Configuring Sendmail as a server for other clients

The default **sendmail.cf** file does not allow Sendmail to accept network connections from any host other than the local computer. To configure Sendmail as a server for other clients, edit the **/etc/mail/sendmail.mc** file, and either change the address specified in the **Addr=** option of the **DAEMON_OPTIONS** directive from **127.0.0.1** to the IP address of an active network device or comment out the **DAEMON_OPTIONS** directive all together by placing **dnl** at the beginning of the line. When finished, regenerate **/etc/mail/sendmail.cf** by restarting the service:

```
systemctl restart sendmail.service
```

The default configuration which ships with Fedora works for most SMTP-only sites. However, it does not work for *UUCP* (*UNIX-to-UNIX Copy Protocol*) sites. If using UUCP mail transfers, the **/etc/mail/sendmail.mc** file must be reconfigured and a new **/etc/mail/sendmail.cf** file must be generated.

Consult the **/usr/share/sendmail-cf/README** file before editing any files in the directories under the **/usr/share/sendmail-cf** directory, as they can affect the future configuration of the **/etc/mail/sendmail.cf** file.

14.3.2.4. Masquerading

One common Sendmail configuration is to have a single machine act as a mail gateway for all machines on the network. For instance, a company may want to have a machine called **mail.example.com** that handles all of their email and assigns a consistent return address to all outgoing mail.

In this situation, the Sendmail server must masquerade the machine names on the company network so that their return address is **user@example.com** instead of **user@host.example.com**.

To do this, add the following lines to **/etc/mail/sendmail.mc**:

```
FEATURE(always_add_domain)dnl
FEATURE(`masquerade_entire_domain')dnl
```

```
FEATURE(`masquerade_envelope')dnl
FEATURE(`allmasquerade')dnl
MASQUERADE_AS(`bigcorp.com.')dnl
MASQUERADE_DOMAIN(`bigcorp.com.')dnl
MASQUERADE_AS(bigcorp.com)dnl
```

After generating a new **sendmail.cf** using the **m4** macro processor, this configuration makes all mail from inside the network appear as if it were sent from **bigcorp.com**.

14.3.2.5. Stopping Spam

Email spam can be defined as unnecessary and unwanted email received by a user who never requested the communication. It is a disruptive, costly, and widespread abuse of Internet communication standards.

Sendmail makes it relatively easy to block new spamming techniques being employed to send junk email. It even blocks many of the more usual spamming methods by default. Main anti-spam features available in sendmail are *header checks*, *relaying denial* (default from version 8.9), *access database and sender information checks*.

For example, forwarding of SMTP messages, also called relaying, has been disabled by default since Sendmail version 8.9. Before this change occurred, Sendmail directed the mail host (**x.edu**) to accept messages from one party (**y.com**) and sent them to a different party (**z.net**). Now, however, Sendmail must be configured to permit any domain to relay mail through the server. To configure relay domains, edit the **/etc/mail/relay-domains** file and restart Sendmail:

```
systemctl restart sendmail.service
```

However, many times users are bombarded with spam from other servers throughout the Internet. In these instances, Sendmail's access control features available through the **/etc/mail/access** file can be used to prevent connections from unwanted hosts. The following example illustrates how this file can be used to both block and specifically allow access to the Sendmail server:

```
badspammer.com ERROR:550 "Go away and do not spam us" tux.badspammer.com OK 10.0 RELAY
```

This example shows that any email sent from **badspammer.com** is blocked with a 550 RFC-821 compliant error code, with a message sent back to the spammer. Email sent from the **tux.badspammer.com** sub-domain, is accepted. The last line shows that any email sent from the 10.0.*.* network can be relayed through the mail server.

Because the **/etc/mail/access.db** file is a database, use the **makemap** command to update any changes. Do this using the following command as `root`:

```
makemap hash /etc/mail/access < /etc/mail/access
```

Message header analysis allows you to reject mail based on header contents. SMTP servers store information about an email's journey in the message header. As the message travels from one MTA to another, each puts in a **Received** header above all the other **Received** headers. It is important to note that this information may be altered by spammers.

The above examples only represent a small part of what Sendmail can do in terms of allowing or blocking access. Refer to the **/usr/share/sendmail-cf/README** for more information and examples.

Since Sendmail calls the Procmail MDA when delivering mail, it is also possible to use a spam filtering program, such as SpamAssassin, to identify and file spam for users. Refer to *Section 14.4.2.6, "Spam Filters"* for more information about using SpamAssassin.

14.3.2.6. Using Sendmail with LDAP

Using LDAP is a very quick and powerful way to find specific information about a particular user from a much larger group. For example, an LDAP server can be used to look up a particular email address from a common corporate directory by the user's last name. In this kind of implementation, LDAP is largely separate from Sendmail, with LDAP storing the hierarchical user information and Sendmail only being given the result of LDAP queries in pre-addressed email messages.

However, Sendmail supports a much greater integration with LDAP, where it uses LDAP to replace separately maintained files, such as **/etc/aliases** and **/etc/mail/virtusertables**, on different mail servers that work together to support a medium- to enterprise-level organization. In short, LDAP abstracts the mail routing level from Sendmail and its separate configuration files to a powerful LDAP cluster that can be leveraged by many different applications.

The current version of Sendmail contains support for LDAP. To extend the Sendmail server using LDAP, first get an LDAP server, such as **OpenLDAP**, running and properly configured. Then edit the **/etc/mail/sendmail.mc** to include the following:

```
LDAPROUTE_DOMAIN('yourdomain.com')dnl
FEATURE('ldap_routing')dnl
```



Advanced configuration

This is only for a very basic configuration of Sendmail with LDAP. The configuration can differ greatly from this depending on the implementation of LDAP, especially when configuring several Sendmail machines to use a common LDAP server.

Consult **/usr/share/sendmail-cf/README** for detailed LDAP routing configuration instructions and examples.

Next, recreate the **/etc/mail/sendmail.cf** file by running the **m4** macro processor and again restarting Sendmail. Refer to *Section 14.3.2.3, "Common Sendmail Configuration Changes"* for instructions.

For more information on LDAP, refer to *Section 15.1, "OpenLDAP"*.

14.3.3. Fetchmail

Fetchmail is an MTA which retrieves email from remote servers and delivers it to the local MTA. Many users appreciate the ability to separate the process of downloading their messages located on a remote server from the process of reading and organizing their email in an MUA. Designed with the needs of dial-up users in mind, Fetchmail connects and quickly downloads all of the email messages to the mail spool file using any number of protocols, including POP3 and IMAP. It can even forward email messages to an SMTP server, if necessary.



Installing the fetchmail package

In order to use **Fetchmail**, first ensure the *fetchmail* package is installed on your system by running, as `root`:

```
yum install fetchmail
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

Fetchmail is configured for each user through the use of a **`.fetchmailrc`** file in the user's home directory. If it does not already exist, create the **`.fetchmailrc`** file in your home directory

Using preferences in the **`.fetchmailrc`** file, Fetchmail checks for email on a remote server and downloads it. It then delivers it to port 25 on the local machine, using the local MTA to place the email in the correct user's spool file. If Procmail is available, it is launched to filter the email and place it in a mailbox so that it can be read by an MUA.

14.3.3.1. Fetchmail Configuration Options

Although it is possible to pass all necessary options on the command line to check for email on a remote server when executing Fetchmail, using a **`.fetchmailrc`** file is much easier. Place any desired configuration options in the **`.fetchmailrc`** file for those options to be used each time the **`fetchmail`** command is issued. It is possible to override these at the time Fetchmail is run by specifying that option on the command line.

A user's **`.fetchmailrc`** file contains three classes of configuration options:

- *global options* — Gives Fetchmail instructions that control the operation of the program or provide settings for every connection that checks for email.
- *server options* — Specifies necessary information about the server being polled, such as the hostname, as well as preferences for specific email servers, such as the port to check or number of seconds to wait before timing out. These options affect every user using that server.
- *user options* — Contains information, such as username and password, necessary to authenticate and check for email using a specified email server.

Global options appear at the top of the **`.fetchmailrc`** file, followed by one or more server options, each of which designate a different email server that Fetchmail should check. User options follow server options for each user account checking that email server. Like server options, multiple user options may be specified for use with a particular server as well as to check multiple email accounts on the same server.

Server options are called into service in the **`.fetchmailrc`** file by the use of a special option verb, **`poll`** or **`skip`**, that precedes any of the server information. The **`poll`** action tells Fetchmail to use this server option when it is run, which checks for email using the specified user options. Any server options after a **`skip`** action, however, are not checked unless this server's hostname is specified when Fetchmail is invoked. The **`skip`** option is useful when testing configurations in the **`.fetchmailrc`** file

because it only checks skipped servers when specifically invoked, and does not affect any currently working configurations.

The following is a sample example of a **.fetchmailrc** file:

```
set postmaster "user1"
set bouncemail

poll pop.domain.com proto pop3
    user 'user1' there with password 'secret' is user1 here

poll mail.domain2.com
    user 'user5' there with password 'secret2' is user1 here
    user 'user7' there with password 'secret3' is user1 here
```

In this example, the global options specify that the user is sent email as a last resort (**postmaster** option) and all email errors are sent to the postmaster instead of the sender (**bouncemail** option). The **set** action tells Fetchmail that this line contains a global option. Then, two email servers are specified, one set to check using POP3, the other for trying various protocols to find one that works. Two users are checked using the second server option, but all email found for any user is sent to **user1**'s mail spool. This allows multiple mailboxes to be checked on multiple servers, while appearing in a single MUA inbox. Each user's specific information begins with the **user** action.



Omitting the password from the configuration

Users are not required to place their password in the **.fetchmailrc** file. Omitting the **with password '*password*'** section causes Fetchmail to ask for a password when it is launched.

Fetchmail has numerous global, server, and local options. Many of these options are rarely used or only apply to very specific situations. The **fetchmail** man page explains each option in detail, but the most common ones are listed in the following three sections.

14.3.3.2. Global Options

Each global option should be placed on a single line after a **set** action.

- **daemon *seconds*** — Specifies daemon-mode, where Fetchmail stays in the background. Replace *seconds* with the number of seconds Fetchmail is to wait before polling the server.
- **postmaster** — Specifies a local user to send mail to in case of delivery problems.
- **syslog** — Specifies the log file for errors and status messages. By default, this is **/var/log/maillog**.

14.3.3.3. Server Options

Server options must be placed on their own line in **.fetchmailrc** after a **poll** or **skip** action.

- **auth *auth-type*** — Replace *auth-type* with the type of authentication to be used. By default, **password** authentication is used, but some protocols support other types of authentication, including **kerberos_v5**, **kerberos_v4**, and **ssh**. If the **any** authentication type is used, Fetchmail

first tries methods that do not require a password, then methods that mask the password, and finally attempts to send the password unencrypted to authenticate to the server.

- **interval *number*** — Polls the specified server every ***number*** of times that it checks for email on all configured servers. This option is generally used for email servers where the user rarely receives messages.
- **port *port-number*** — Replace *port-number* with the port number. This value overrides the default port number for the specified protocol.
- **proto *protocol*** — Replace *protocol* with the protocol, such as **pop3** or **imap**, to use when checking for messages on the server.
- **timeout *seconds*** — Replace *seconds* with the number of seconds of server inactivity after which Fetchmail gives up on a connection attempt. If this value is not set, a default of **300** seconds is assumed.

14.3.3.4. User Options

User options may be placed on their own lines beneath a server option or on the same line as the server option. In either case, the defined options must follow the **user** option (defined below).

- **fetchall** — Orders Fetchmail to download all messages in the queue, including messages that have already been viewed. By default, Fetchmail only pulls down new messages.
- **fetchlimit *number*** — Replace *number* with the number of messages to be retrieved before stopping.
- **flush** — Deletes all previously viewed messages in the queue before retrieving new messages.
- **limit *max-number-bytes*** — Replace *max-number-bytes* with the maximum size in bytes that messages are allowed to be when retrieved by Fetchmail. This option is useful with slow network links, when a large message takes too long to download.
- **password '*password*'** — Replace *password* with the user's password.
- **preconnect "*command*"** — Replace *command* with a command to be executed before retrieving messages for the user.
- **postconnect "*command*"** — Replace *command* with a command to be executed after retrieving messages for the user.
- **ssl** — Activates SSL encryption.
- **user "*username*"** — Replace *username* with the username used by Fetchmail to retrieve messages. *This option must precede all other user options.*

14.3.3.5. Fetchmail Command Options

Most Fetchmail options used on the command line when executing the **fetchmail** command mirror the **.fetchmailrc** configuration options. In this way, Fetchmail may be used with or without a configuration file. These options are not used on the command line by most users because it is easier to leave them in the **.fetchmailrc** file.

There may be times when it is desirable to run the **fetchmail** command with other options for a particular purpose. It is possible to issue command options to temporarily override a **.fetchmailrc** setting that is causing an error, as any options specified at the command line override configuration file options.

14.3.3.6. Informational or Debugging Options

Certain options used after the **fetchmail** command can supply important information.

- **--configdump** — Displays every possible option based on information from **.fetchmailrc** and Fetchmail defaults. No email is retrieved for any users when using this option.
- **-s** — Executes Fetchmail in silent mode, preventing any messages, other than errors, from appearing after the **fetchmail** command.
- **-v** — Executes Fetchmail in verbose mode, displaying every communication between Fetchmail and remote email servers.
- **-V** — Displays detailed version information, lists its global options, and shows settings to be used with each user, including the email protocol and authentication method. No email is retrieved for any users when using this option.

14.3.3.7. Special Options

These options are occasionally useful for overriding defaults often found in the **.fetchmailrc** file.

- **-a** — Fetchmail downloads all messages from the remote email server, whether new or previously viewed. By default, Fetchmail only downloads new messages.
- **-k** — Fetchmail leaves the messages on the remote email server after downloading them. This option overrides the default behavior of deleting messages after downloading them.
- **-l *max-number-bytes*** — Fetchmail does not download any messages over a particular size and leaves them on the remote email server.
- **--quit** — Quits the Fetchmail daemon process.

More commands and **.fetchmailrc** options can be found in the **fetchmail** man page.

14.3.4. Mail Transport Agent (MTA) Configuration

A *Mail Transport Agent* (MTA) is essential for sending email. A *Mail User Agent* (MUA) such as **Evolution**, **Thunderbird**, and **Mutt**, is used to read and compose email. When a user sends an email from an MUA, the message is handed off to the MTA, which sends the message through a series of MTAs until it reaches its destination.

Even if a user does not plan to send email from the system, some automated tasks or system programs might use the **/bin/mail** command to send email containing log messages to the `root` user of the local system.

Fedora 17 provides two MTAs: Postfix and Sendmail. If both are installed, Postfix is the default MTA.

14.4. Mail Delivery Agents

Fedora includes two primary MDAs, Procmail and **mail**. Both of the applications are considered LDAs and both move email from the MTA's spool file into the user's mailbox. However, Procmail provides a robust filtering system.

This section details only Procmail. For information on the **mail** command, consult its man page (**man mail**).

Procmail delivers and filters email as it is placed in the mail spool file of the localhost. It is powerful, gentle on system resources, and widely used. Procmail can play a critical role in delivering email to be read by email client applications.

Procmail can be invoked in several different ways. Whenever an MTA places an email into the mail spool file, Procmail is launched. Procmail then filters and files the email for the MUA and quits. Alternatively, the MUA can be configured to execute Procmail any time a message is received so that messages are moved into their correct mailboxes. By default, the presence of **/etc/procmailrc** or of a **~/.procmailrc** file (also called an *rc* file) in the user's home directory invokes Procmail whenever an MTA receives a new message.

By default, no system-wide **rc** files exist in the **/etc/** directory and no **.procmailrc** files exist in any user's home directory. Therefore, to use Procmail, each user must construct a **.procmailrc** file with specific environment variables and rules.

Whether Procmail acts upon an email message depends upon whether the message matches a specified set of conditions or *recipes* in the **rc** file. If a message matches a recipe, then the email is placed in a specified file, is deleted, or is otherwise processed.

When Procmail starts, it reads the email message and separates the body from the header information. Next, Procmail looks for a **/etc/procmailrc** file and **rc** files in the **/etc/procmailrcs** directory for default, system-wide, Procmail environmental variables and recipes. Procmail then searches for a **.procmailrc** file in the user's home directory. Many users also create additional **rc** files for Procmail that are referred to within the **.procmailrc** file in their home directory.

14.4.1. Procmail Configuration

The Procmail configuration file contains important environmental variables. These variables specify things such as which messages to sort and what to do with the messages that do not match any recipes.

These environmental variables usually appear at the beginning of the **~/.procmailrc** file in the following format:

```
env-variable="value"
```

In this example, ***env-variable*** is the name of the variable and ***value*** defines the variable.

There are many environment variables not used by most Procmail users and many of the more important environment variables are already defined by a default value. Most of the time, the following variables are used:

- **DEFAULT** — Sets the default mailbox where messages that do not match any recipes are placed.

  The default **DEFAULT** value is the same as **$ORGMAIL**.

- **INCLUDERC** — Specifies additional **rc** files containing more recipes for messages to be checked against. This breaks up the Procmail recipe lists into individual files that fulfill different roles, such as blocking spam and managing email lists, that can then be turned off or on by using comment characters in the user's **~/.procmailrc** file.

  For example, lines in a user's **.procmailrc** file may look like this:

  ```
  MAILDIR=$HOME/Msgs INCLUDERC=$MAILDIR/lists.rc INCLUDERC=$MAILDIR/spam.rc
  ```

  To turn off Procmail filtering of email lists but leaving spam control in place, comment out the first **INCLUDERC** line with a hash sign (#).

- **LOCKSLEEP** — Sets the amount of time, in seconds, between attempts by Procmail to use a particular lockfile. The default is 8 seconds.

- **LOCKTIMEOUT** — Sets the amount of time, in seconds, that must pass after a lockfile was last modified before Procmail assumes that the lockfile is old and can be deleted. The default is 1024 seconds.

- **LOGFILE** — The file to which any Procmail information or error messages are written.

- **MAILDIR** — Sets the current working directory for Procmail. If set, all other Procmail paths are relative to this directory.

- **ORGMAIL** — Specifies the original mailbox, or another place to put the messages if they cannot be placed in the default or recipe-required location.

  By default, a value of **/var/spool/mail/$LOGNAME** is used.

- **SUSPEND** — Sets the amount of time, in seconds, that Procmail pauses if a necessary resource, such as swap space, is not available.

- **SWITCHRC** — Allows a user to specify an external file containing additional Procmail recipes, much like the **INCLUDERC** option, except that recipe checking is actually stopped on the referring configuration file and only the recipes on the **SWITCHRC**-specified file are used.

- **VERBOSE** — Causes Procmail to log more information. This option is useful for debugging.

Other important environmental variables are pulled from the shell, such as **LOGNAME**, which is the login name; **HOME**, which is the location of the home directory; and **SHELL**, which is the default shell.

A comprehensive explanation of all environments variables, as well as their default values, is available in the **procmailrc** man page.

14.4.2. Procmail Recipes

New users often find the construction of recipes the most difficult part of learning to use Procmail. To some extent, this is understandable, as recipes do their message matching using *regular expressions*, which is a particular format used to specify qualifications for a matching string. However, regular expressions are not very difficult to construct and even less difficult to understand when read. Additionally, the consistency of the way Procmail recipes are written, regardless of regular expressions, makes it easy to learn by example. To see example Procmail recipes, refer to *Section 14.4.2.5, "Recipe Examples"*.

Procmail recipes take the following form:

```
:0flags: lockfile-name * special-condition-character
        condition-1 * special-condition-character
        condition-2 * special-condition-character
        condition-N
        special-action-character
        action-to-perform
```

The first two characters in a Procmail recipe are a colon and a zero. Various flags can be placed after the zero to control how Procmail processes the recipe. A colon after the ***flags*** section specifies that a lockfile is created for this message. If a lockfile is created, the name can be specified by replacing ***lockfile-name*** .

A recipe can contain several conditions to match against the message. If it has no conditions, every message matches the recipe. Regular expressions are placed in some conditions to facilitate message matching. If multiple conditions are used, they must all match for the action to be performed. Conditions are checked based on the flags set in the recipe's first line. Optional special characters placed after the asterisk character (*****) can further control the condition.

The ***action-to-perform*** argument specifies the action taken when the message matches one of the conditions. There can only be one action per recipe. In many cases, the name of a mailbox is used here to direct matching messages into that file, effectively sorting the email. Special action characters may also be used before the action is specified. Refer to *Section 14.4.2.4, "Special Conditions and Actions"* for more information.

14.4.2.1. Delivering vs. Non-Delivering Recipes

The action used if the recipe matches a particular message determines whether it is considered a *delivering* or *non-delivering* recipe. A delivering recipe contains an action that writes the message to a file, sends the message to another program, or forwards the message to another email address. A non-delivering recipe covers any other actions, such as a *nesting block*. A nesting block is a set of actions, contained in braces **{ }**, that are performed on messages which match the recipe's conditions. Nesting blocks can be nested inside one another, providing greater control for identifying and performing actions on messages.

When messages match a delivering recipe, Procmail performs the specified action and stops comparing the message against any other recipes. Messages that match non-delivering recipes continue to be compared against other recipes.

14.4.2.2. Flags

Flags are essential to determine how or if a recipe's conditions are compared to a message. The following flags are commonly used:

- **A** — Specifies that this recipe is only used if the previous recipe without an **A** or **a** flag also matched this message.
- **a** — Specifies that this recipe is only used if the previous recipe with an **A** or **a** flag also matched this message *and* was successfully completed.
- **B** — Parses the body of the message and looks for matching conditions.
- **b** — Uses the body in any resulting action, such as writing the message to a file or forwarding it. This is the default behavior.

- **c** — Generates a carbon copy of the email. This is useful with delivering recipes, since the required action can be performed on the message and a copy of the message can continue being processed in the **rc** files.
- **D** — Makes the **egrep** comparison case-sensitive. By default, the comparison process is not case-sensitive.
- **E** — While similar to the **A** flag, the conditions in the recipe are only compared to the message if the immediately preceding the recipe without an **E** flag did not match. This is comparable to an *else* action.
- **e** — The recipe is compared to the message only if the action specified in the immediately preceding recipe fails.
- **f** — Uses the pipe as a filter.
- **H** — Parses the header of the message and looks for matching conditions. This is the default behavior.
- **h** — Uses the header in a resulting action. This is the default behavior.
- **w** — Tells Procmail to wait for the specified filter or program to finish, and reports whether or not it was successful before considering the message filtered.
- **W** — Is identical to **w** except that "Program failure" messages are suppressed.

For a detailed list of additional flags, refer to the **procmailrc** man page.

14.4.2.3. Specifying a Local Lockfile

Lockfiles are very useful with Procmail to ensure that more than one process does not try to alter a message simultaneously. Specify a local lockfile by placing a colon (**:**) after any flags on a recipe's first line. This creates a local lockfile based on the destination file name plus whatever has been set in the **LOCKEXT** global environment variable.

Alternatively, specify the name of the local lockfile to be used with this recipe after the colon.

14.4.2.4. Special Conditions and Actions

Special characters used before Procmail recipe conditions and actions change the way they are interpreted.

The following characters may be used after the asterisk character (*****) at the beginning of a recipe's condition line:

- **!** — In the condition line, this character inverts the condition, causing a match to occur only if the condition does not match the message.
- **<** — Checks if the message is under a specified number of bytes.
- **>** — Checks if the message is over a specified number of bytes.

The following characters are used to perform special actions:

- **!** — In the action line, this character tells Procmail to forward the message to the specified email addresses.

- **$** — Refers to a variable set earlier in the **rc** file. This is often used to set a common mailbox that is referred to by various recipes.
- **|** — Starts a specified program to process the message.
- **{** and **}** — Constructs a nesting block, used to contain additional recipes to apply to matching messages.

If no special character is used at the beginning of the action line, Procmail assumes that the action line is specifying the mailbox in which to write the message.

14.4.2.5. Recipe Examples

Procmail is an extremely flexible program, but as a result of this flexibility, composing Procmail recipes from scratch can be difficult for new users.

The best way to develop the skills to build Procmail recipe conditions stems from a strong understanding of regular expressions combined with looking at many examples built by others. A thorough explanation of regular expressions is beyond the scope of this section. The structure of Procmail recipes and useful sample Procmail recipes can be found at various places on the Internet (such as *http://www.iki.fi/era/procmail/links.html*). The proper use and adaptation of regular expressions can be derived by viewing these recipe examples. In addition, introductory information about basic regular expression rules can be found in the **grep** man page.

The following simple examples demonstrate the basic structure of Procmail recipes and can provide the foundation for more intricate constructions.

A basic recipe may not even contain conditions, as is illustrated in the following example:

```
:0: new-mail.spool
```

The first line specifies that a local lockfile is to be created but does not specify a name, so Procmail uses the destination file name and appends the value specified in the **LOCKEXT** environment variable. No condition is specified, so every message matches this recipe and is placed in the single spool file called **new-mail.spool**, located within the directory specified by the **MAILDIR** environment variable. An MUA can then view messages in this file.

A basic recipe, such as this, can be placed at the end of all **rc** files to direct messages to a default location.

The following example matched messages from a specific email address and throws them away.

```
:0 * ^From: spammer@domain.com /dev/null
```

With this example, any messages sent by **spammer@domain.com** are sent to the **/dev/null** device, deleting them.



Sending messages to /dev/null

Be certain that rules are working as intended before sending messages to **/dev/null** for permanent deletion. If a recipe inadvertently catches unintended messages, and those messages disappear, it becomes difficult to troubleshoot the rule.

A better solution is to point the recipe's action to a special mailbox, which can be checked from time to time to look for false positives. Once satisfied that no messages are accidentally being matched, delete the mailbox and direct the action to send the messages to **/dev/null**.

The following recipe grabs email sent from a particular mailing list and places it in a specified folder.

```
:0: * ^(From|Cc|To).*tux-lug tuxlug
```

Any messages sent from the **tux-lug@domain.com** mailing list are placed in the **tuxlug** mailbox automatically for the MUA. Note that the condition in this example matches the message if it has the mailing list's email address on the **From**, **Cc**, or **To** lines.

Consult the many Procmail online resources available in *Section 14.6, "Additional Resources"* for more detailed and powerful recipes.

14.4.2.6. Spam Filters

Because it is called by Sendmail, Postfix, and Fetchmail upon receiving new emails, Procmail can be used as a powerful tool for combating spam.

This is particularly true when Procmail is used in conjunction with SpamAssassin. When used together, these two applications can quickly identify spam emails, and sort or destroy them.

SpamAssassin uses header analysis, text analysis, blacklists, a spam-tracking database, and self-learning Bayesian spam analysis to quickly and accurately identify and tag spam.



Installing the spamassassin package

In order to use **SpamAssassin**, first ensure the *spamassassin* package is installed on your system by running, as `root`:

```
yum install spamassassin
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

The easiest way for a local user to use SpamAssassin is to place the following line near the top of the **~/.procmailrc** file:

```
INCLUDERC=/etc/mail/spamassassin/spamassassin-default.rc
```

The **/etc/mail/spamassassin/spamassassin-default.rc** contains a simple Procmail rule that activates SpamAssassin for all incoming email. If an email is determined to be spam, it is tagged in the header as such and the title is prepended with the following pattern:

```
*****SPAM*****
```

The message body of the email is also prepended with a running tally of what elements caused it to be diagnosed as spam.

To file email tagged as spam, a rule similar to the following can be used:

```
:0 Hw * ^X-Spam-Status: Yes spam
```

This rule files all email tagged in the header as spam into a mailbox called **spam**.

Since SpamAssassin is a Perl script, it may be necessary on busy servers to use the binary SpamAssassin daemon (`spamd`) and the client application (**spamc**). Configuring SpamAssassin this way, however, requires `root` access to the host.

To start the `spamd` daemon, type the following command:

```
systemctl start spamassassin.service
```

To start the SpamAssassin daemon when the system is booted, run:

```
systemctl enable spamassassin.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

To configure Procmail to use the SpamAssassin client application instead of the Perl script, place the following line near the top of the **~/.procmailrc** file. For a system-wide configuration, place it in **/etc/procmailrc**:

```
INCLUDERC=/etc/mail/spamassassin/spamassassin-spamc.rc
```

14.5. Mail User Agents

Fedora offers a variety of email programs, both, graphical email client programs, such as **Evolution**, and text-based email programs such as **mutt**.

The remainder of this section focuses on securing communication between a client and a server.

14.5.1. Securing Communication

Popular MUAs included with Fedora, such as **Evolution** and **mutt** offer SSL-encrypted email sessions.

Like any other service that flows over a network unencrypted, important email information, such as usernames, passwords, and entire messages, may be intercepted and viewed by users on the

network. Additionally, since the standard POP and IMAP protocols pass authentication information unencrypted, it is possible for an attacker to gain access to user accounts by collecting usernames and passwords as they are passed over the network.

14.5.1.1. Secure Email Clients

Most Linux MUAs designed to check email on remote servers support SSL encryption. To use SSL when retrieving email, it must be enabled on both the email client and the server.

SSL is easy to enable on the client-side, often done with the click of a button in the MUA's configuration window or via an option in the MUA's configuration file. Secure IMAP and POP have known port numbers (993 and 995, respectively) that the MUA uses to authenticate and download messages.

14.5.1.2. Securing Email Client Communications

Offering SSL encryption to IMAP and POP users on the email server is a simple matter.

First, create an SSL certificate. This can be done in two ways: by applying to a *Certificate Authority* (*CA*) for an SSL certificate or by creating a self-signed certificate.



Avoid using self-signed certificates

Self-signed certificates should be used for testing purposes only. Any server used in a production environment should use an SSL certificate granted by a CA.

To create a self-signed SSL certificate for IMAP or POP, change to the **/etc/pki/dovecot/** directory, edit the certificate parameters in the **/etc/pki/dovecot/dovecot-openssl.conf** configuration file as you prefer, and type the following commands, as root:

```
dovecot]# rm -f certs/dovecot.pem private/dovecot.pem
dovecot]# /usr/libexec/dovecot/mkcert.sh
```

Once finished, make sure you have the following configurations in your **/etc/dovecot/conf.d/10-ssl.conf** file:

```
ssl_cert = </etc/pki/dovecot/certs/dovecot.pem
ssl_key = </etc/pki/dovecot/private/dovecot.pem
```

Execute the **systemctl restart dovecot.service** command to restart the **dovecot** daemon.

Alternatively, the **stunnel** command can be used as an SSL encryption wrapper around the standard, non-secure connections to IMAP or POP services.

The **stunnel** utility uses external OpenSSL libraries included with Fedora to provide strong cryptography and to protect the network connections. It is recommended to apply to a CA to obtain an SSL certificate, but it is also possible to create a self-signed certificate.



Installing the stunnel package

In order to use **stunnel**, first ensure the *stunnel* package is installed on your system by running, as `root`:

```
yum install stunnel
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

To create a self-signed SSL certificate, change to the **/etc/pki/tls/certs/** directory, and type the following command:

```
certs]# make stunnel.pem
```

Answer all of the questions to complete the process.

Once the certificate is generated, create an **stunnel** configuration file, for example **/etc/stunnel/mail.conf**, with the following content:

```
cert = /etc/pki/tls/certs/stunnel.pem

[pop3s]
accept  = 995
connect = 110

[imaps]
accept  = 993
connect = 143
```

Once you start **stunnel** with the created configuration file using the **/usr/bin/stunnel /etc/stunnel/mail.conf** command, it will be possible to use an IMAP or a POP email client and connect to the email server using SSL encryption.

For more information on **stunnel**, refer to the **stunnel** man page or the documents in the **/usr/share/doc/stunnel-*version-number*** / directory, where *version-number* is the version number of **stunnel**.

14.6. Additional Resources

The following is a list of additional documentation about email applications.

14.6.1. Installed Documentation

- Information on configuring Sendmail is included with the **sendmail** and **sendmail-cf** packages.
  - **/usr/share/sendmail-cf/README** — Contains information on the **m4** macro processor, file locations for Sendmail, supported mailers, how to access enhanced features, and more.

In addition, the **sendmail** and **aliases** man pages contain helpful information covering various Sendmail options and the proper configuration of the Sendmail **/etc/mail/aliases** file.

- **/usr/share/doc/postfix-*version-number*** — Contains a large amount of information about ways to configure Postfix. Replace *version-number* with the version number of Postfix.
- **/usr/share/doc/fetchmail-*version-number*** — Contains a full list of Fetchmail features in the **FEATURES** file and an introductory **FAQ** document. Replace *version-number* with the version number of Fetchmail.
- **/usr/share/doc/procmail-*version-number*** — Contains a **README** file that provides an overview of Procmail, a **FEATURES** file that explores every program feature, and an **FAQ** file with answers to many common configuration questions. Replace *version-number* with the version number of Procmail.

  When learning how Procmail works and creating new recipes, the following Procmail man pages are invaluable:

  - **procmail** — Provides an overview of how Procmail works and the steps involved with filtering email.
  - **procmailrc** — Explains the **rc** file format used to construct recipes.
  - **procmailex** — Gives a number of useful, real-world examples of Procmail recipes.
  - **procmailsc** — Explains the weighted scoring technique used by Procmail to match a particular recipe to a message.
  - **/usr/share/doc/spamassassin-*version-number*/** — Contains a large amount of information pertaining to SpamAssassin. Replace *version-number* with the version number of the **spamassassin** package.

14.6.2. Useful Websites

- *http://www.sendmail.org/* — Offers a thorough technical breakdown of Sendmail features, documentation and configuration examples.
- *http://www.sendmail.com/* — Contains news, interviews and articles concerning Sendmail, including an expanded view of the many options available.
- *http://www.postfix.org/* — The Postfix project home page contains a wealth of information about Postfix. The mailing list is a particularly good place to look for information.
- *http://fetchmail.berlios.de/* — The home page for Fetchmail, featuring an online manual, and a thorough FAQ.
- *http://www.procmail.org/* — The home page for Procmail with links to assorted mailing lists dedicated to Procmail as well as various FAQ documents.
- *http://partmaps.org/era/procmail/mini-faq.html* — An excellent Procmail FAQ, offers troubleshooting tips, details about file locking, and the use of wildcard characters.
- *http://www.uwasa.fi/~ts/info/proctips.html* — Contains dozens of tips that make using Procmail much easier. Includes instructions on how to test **.procmailrc** files and use Procmail scoring to decide if a particular action should be taken.

- *http://www.spamassassin.org/* — The official site of the SpamAssassin project.

14.6.3. Related Books

- *Sendmail Milters: A Guide for Fighting Spam* by Bryan Costales and Marcia Flynt; Addison-Wesley — A good Sendmail guide that can help you customize your mail filters.
- *Sendmail* by Bryan Costales with Eric Allman et al.; O'Reilly & Associates — A good Sendmail reference written with the assistance of the original creator of Delivermail and Sendmail.
- *Removing the Spam: Email Processing and Filtering* by Geoff Mulligan; Addison-Wesley Publishing Company — A volume that looks at various methods used by email administrators using established tools, such as Sendmail and Procmail, to manage spam problems.
- *Internet Email Protocols: A Developer's Guide* by Kevin Johnson; Addison-Wesley Publishing Company — Provides a very thorough review of major email protocols and the security they provide.
- *Managing IMAP* by Dianna Mullet and Kevin Mullet; O'Reilly & Associates — Details the steps required to configure an IMAP server.

Directory Servers

15.1. OpenLDAP

LDAP (Lightweight Directory Access Protocol) is a set of open protocols used to access centrally stored information over a network. It is based on the `X.500` standard for directory sharing, but is less complex and resource-intensive. For this reason, LDAP is sometimes referred to as “X.500 Lite”.

Like X.500, LDAP organizes information in a hierarchical manner using directories. These directories can store a variety of information such as names, addresses, or phone numbers, and can even be used in a manner similar to the *Network Information Service* (NIS), enabling anyone to access their account from any machine on the LDAP enabled network.

LDAP is commonly used for centrally managed users and groups, user authentication, or system configuration. It can also serve as a virtual phone directory, allowing users to easily access contact information for other users. Additionally, it can refer a user to other LDAP servers throughout the world, and thus provide an ad-hoc global repository of information. However, it is most frequently used within individual organizations such as universities, government departments, and private companies.

This section covers the installation and configuration of **OpenLDAP 2.4**, an open source implementation of the LDAPv2 and LDAPv3 protocols.

15.1.1. Introduction to LDAP

Using a client/server architecture, LDAP provides reliable means to create a central information directory accessible from the network. When a client attempts to modify information within this directory, the server verifies the user has permission to make the change, and then adds or updates the entry as requested. To ensure the communication is secure, the *Secure Sockets Layer* (SSL) or *Transport Layer Security* (TLS) cryptographic protocols can be used to prevent an attacker from intercepting the transmission.



Using Mozilla NSS

The OpenLDAP suite in Fedora 17 no longer uses OpenSSL. Instead, it uses the Mozilla implementation of *Network Security Services* (NSS). OpenLDAP continues to work with existing certificates, keys, and other TLS configuration. For more information on how to configure it to use Mozilla certificate and key database, refer to *How do I use TLS/SSL with Mozilla NSS*[1].

The LDAP server supports several database systems, which gives administrators the flexibility to choose the best suited solution for the type of information they are planning to serve. Because of a well-defined client *Application Programming Interface* (API), the number of applications able to communicate with an LDAP server is numerous, and increasing in both quantity and quality.

15.1.1.1. LDAP Terminology

The following is a list of LDAP-specific terms that are used within this chapter:

[1] http://www.openldap.org/faq/index.cgi?file=1514

entry
A single unit within an LDAP directory. Each entry is identified by its unique *Distinguished Name* (DN).

attribute
Information directly associated with an entry. For example, if an organization is represented as an LDAP entry, attributes associated with this organization might include an address, a fax number, etc. Similarly, people can be represented as entries with common attributes such as personal telephone number or email address.

An attribute can either have a single value, or an unordered space-separated list of values. While certain attributes are optional, other are required. Required attributes are specified using the **`objectClass`** definition, and can be found in schema files located in the **`/etc/openldap/slapd.d/cn=config/cn=schema/`** directory.

The assertion of an attribute and its corresponding value is also referred to as a *Relative Distinguished Name* (RDN). Unlike distinguished names that are unique globally, a relative distinguished name is only unique per entry.

LDIF
The *LDAP Data Interchange Format* (LDIF) is a plain text representation of an LDAP entry. It takes the following form:

```
[id] dn: distinguished_name
attribute_type: attribute_value…
attribute_type: attribute_value…
…
```

The optional *`id`* is a number determined by the application that is used to edit the entry. Each entry can contain as many *`attribute_type`* and *`attribute_value`* pairs as needed, as long as they are all defined in a corresponding schema file. A blank line indicates the end of an entry.

15.1.1.2. OpenLDAP Features

OpenLDAP suite provides a number of important features:

- *LDAPv3 Support* — Many of the changes in the protocol since LDAP version 2 are designed to make LDAP more secure. Among other improvements, this includes the support for Simple Authentication and Security Layer (SASL), Transport Layer Security (TLS), and Secure Sockets Layer (SSL) protocols.
- *LDAP Over IPC* — The use of inter-process communication (IPC) enhances security by eliminating the need to communicate over a network.
- *IPv6 Support* — OpenLDAP is compliant with Internet Protocol version 6 (IPv6), the next generation of the Internet Protocol.
- *LDIFv1 Support* — OpenLDAP is fully compliant with LDIF version 1.
- *Updated C API* — The current C API improves the way programmers can connect to and use LDAP directory servers.
- *Enhanced Standalone LDAP Server* — This includes an updated access control system, thread pooling, better tools, and much more.

15.1.1.3. OpenLDAP Server Setup

The typical steps to set up an LDAP server on Fedora are as follows:

1. Install the OpenLDAP suite. Refer to *Section 15.1.2, "Installing the OpenLDAP Suite"* for more information on required packages.
2. Customize the configuration as described in *Section 15.1.3, "Configuring an OpenLDAP Server"*.
3. Start the `slapd` service as described in *Section 15.1.4, "Running an OpenLDAP Server"*.
4. Use the **`ldapadd`** utility to add entries to the LDAP directory.
5. Use the **`ldapsearch`** utility to verify that the `slapd` service is accessing the information correctly.

15.1.2. Installing the OpenLDAP Suite

The suite of OpenLDAP libraries and tools is provided by the following packages:

Table 15.1. List of OpenLDAP packages

Package	Description
openldap	A package containing the libraries necessary to run the OpenLDAP server and client applications.
openldap-clients	A package containing the command line utilities for viewing and modifying directories on an LDAP server.
openldap-servers	A package containing both the services and utilities to configure and run an LDAP server. This includes the *Standalone LDAP Daemon*, `slapd`.
openldap-servers-sql	A package containing the SQL support module.

Additionally, the following packages are commonly used along with the LDAP server:

Table 15.2. List of commonly installed additional LDAP packages

Package	Description
nss-pam-ldapd	A package containing `nslcd`, a local LDAP name service that allows a user to perform local LDAP queries.
mod_authz_ldap	A package containing `mod_authz_ldap`, the LDAP authorization module for the Apache HTTP Server. This module uses the short form of the distinguished name for a subject and the issuer of the client SSL certificate to determine the distinguished name of the user within an LDAP directory. It is also capable of authorizing users based on attributes of that user's LDAP directory entry, determining access to assets based on the user and group privileges of the asset, and denying access for users with expired passwords. Note that the `mod_ssl` module is required when using the `mod_authz_ldap` module.

To install these packages, use the **`yum`** command in the following form:

```
yum install package…
```

For example, to perform the basic LDAP server installation, type the following at a shell prompt as `root`:

```
yum install openldap openldap-clients openldap-servers
```

Note that you must have superuser privileges (that is, you must be logged in as `root`) to run this command. For more information on how to install new packages in Fedora, refer to *Section 4.2.4, "Installing Packages"*.

15.1.2.1. Overview of OpenLDAP Server Utilities

To perform administrative tasks, the *openldap-servers* package installs the following utilities along with the `slapd` service:

Table 15.3. List of OpenLDAP server utilities

Command	Description
slapacl	Allows you to check the access to a list of attributes.
slapadd	Allows you to add entries from an LDIF file to an LDAP directory.
slapauth	Allows you to check a list of IDs for authentication and authorization permissions.
slapcat	Allows you to pull entries from an LDAP directory in the default format and save them in an LDIF file.
slapdn	Allows you to check a list of Distinguished Names (DNs) based on available schema syntax.
slapindex	Allows you to re-index the `slapd` directory based on the current content. Run this utility whenever you change indexing options in the configuration file.
slappasswd	Allows you to create an encrypted user password to be used with the **ldapmodify** utility, or in the `slapd` configuration file.
slapschema	Allows you to check the compliance of a database with the corresponding schema.
slaptest	Allows you to check the LDAP server configuration.

For a detailed description of these utilities and their usage, refer to the corresponding manual pages as referred to in *Section 15.1.6.1, "Installed Documentation"*.



Make sure the files have correct owner

Although only `root` can run **slapadd**, the `slapd` service runs as the `ldap` user. Because of this, the directory server is unable to modify any files created by **slapadd**. To correct this issue, after running the **slapadd** utility, type the following at a shell prompt:

```
chown -R ldap:ldap /var/lib/ldap
```



Stop slapd before using these utilities

To preserve the data integrity, stop the `slapd` service before using **`slapadd`**, **`slapcat`**, or **`slapindex`**. You can do so by typing the following at a shell prompt as `root`:

```
systemctl stop slapd.service
```

For more information on how to start, stop, restart, and check the current status of the `slapd` service, refer to *Section 15.1.4, "Running an OpenLDAP Server"*.

15.1.2.2. Overview of OpenLDAP Client Utilities

The *openldap-clients* package installs the following utilities which can be used to add, modify, and delete entries in an LDAP directory:

Table 15.4. List of OpenLDAP client utilities

Command	Description
`ldapadd`	Allows you to add entries to an LDAP directory, either from a file, or from standard input. It is a symbolic link to **`ldapmodify -a`**.
`ldapcompare`	Allows you to compare given attribute with an LDAP directory entry.
`ldapdelete`	Allows you to delete entries from an LDAP directory.
`ldapexop`	Allows you to perform extended LDAP operations.
`ldapmodify`	Allows you to modify entries in an LDAP directory, either from a file, or from standard input.
`ldapmodrdn`	Allows you to modify the RDN value of an LDAP directory entry.
`ldappasswd`	Allows you to set or change the password for an LDAP user.
`ldapsearch`	Allows you to search LDAP directory entries.
`ldapurl`	Allows you to compose or decompose LDAP URLs.
`ldapwhoami`	Allows you to perform a **`whoami`** operation on an LDAP server.

With the exception of **`ldapsearch`**, each of these utilities is more easily used by referencing a file containing the changes to be made rather than typing a command for each entry to be changed within an LDAP directory. The format of such a file is outlined in the man page for each utility.

15.1.2.3. Overview of Common LDAP Client Applications

Although there are various graphical LDAP clients capable of creating and modifying directories on the server, none of them is included in Fedora. Popular applications that can access directories in a read-only mode include **Mozilla Thunderbird**, **Evolution**, or **Ekiga**.

15.1.3. Configuring an OpenLDAP Server

By default, the OpenLDAP configuration is stored in the **`/etc/openldap/`** directory. The following table highlights the most important directories and files within this directory:

Table 15.5. List of OpenLDAP configuration files and directories

Path	Description
/etc/openldap/ldap.conf	The configuration file for client applications that use the OpenLDAP libraries. This includes **ldapadd**, **ldapsearch**, **Evolution**, etc.
/etc/openldap/slapd.d/	The directory containing the slapd configuration.

Note that OpenLDAP no longer reads its configuration from the **/etc/openldap/slapd.conf** file. Instead, it uses a configuration database located in the **/etc/openldap/slapd.d/** directory. If you have an existing **slapd.conf** file from a previous installation, you can convert it to the new format by running the following command as root:

```
slaptest -f /etc/openldap/slapd.conf -F /etc/openldap/slapd.d/
```

The slapd configuration consists of LDIF entries organized in a hierarchical directory structure, and the recommended way to edit these entries is to use the server utilities described in *Section 15.1.2.1, "Overview of OpenLDAP Server Utilities"*.



Do not edit LDIF files directly

An error in an LDIF file can render the slapd service unable to start. Because of this, it is strongly advised that you avoid editing the LDIF files within the **/etc/openldap/slapd.d/** directly.

15.1.3.1. Changing the Global Configuration

Global configuration options for the LDAP server are stored in the **/etc/openldap/slapd.d/cn=config.ldif** file. The following directives are commonly used:

olcAllows

The **olcAllows** directive allows you to specify which features to enable. It takes the following form:

```
olcAllows: feature…
```

It accepts a space-separated list of features as described in *Table 15.6, "Available olcAllows options"*. The default option is **bind_v2**.

Table 15.6. Available olcAllows options

Option	Description
bind_v2	Enables the acceptance of LDAP version 2 bind requests.
bind_anon_cred	Enables an anonymous bind when the Distinguished Name (DN) is empty.
bind_anon_dn	Enables an anonymous bind when the Distinguished Name (DN) is *not* empty.
update_anon	Enables processing of anonymous update operations.

Option	Description
proxy_authz_anon	Enables processing of anonymous proxy authorization control.

Example 15.1. Using the olcAllows directive

```
olcAllows: bind_v2 update_anon
```

olcConnMaxPending

The **olcConnMaxPending** directive allows you to specify the maximum number of pending requests for an anonymous session. It takes the following form:

```
olcConnMaxPending: number
```

The default option is **100**.

Example 15.2. Using the olcConnMaxPending directive

```
olcConnMaxPending: 100
```

olcConnMaxPendingAuth

The **olcConnMaxPendingAuth** directive allows you to specify the maximum number of pending requests for an authenticated session. It takes the following form:

```
olcConnMaxPendingAuth: number
```

The default option is **1000**.

Example 15.3. Using the olcConnMaxPendingAuth directive

```
olcConnMaxPendingAuth: 1000
```

olcDisallows

The **olcDisallows** directive allows you to specify which features to disable. It takes the following form:

```
olcDisallows: feature…
```

It accepts a space-separated list of features as described in *Table 15.7, "Available olcDisallows options"*. No features are disabled by default.

Table 15.7. Available olcDisallows options

Option	Description
bind_anon	Disables the acceptance of anonymous bind requests.
bind_simple	Disables the simple bind authentication mechanism.
tls_2_anon	Disables the enforcing of an anonymous session when the STARTTLS command is received.
tls_authc	Disallows the STARTTLS command when authenticated.

Example 15.4. Using the olcDisallows directive

```
olcDisallows: bind_anon
```

olcIdleTimeout

The **olcIdleTimeout** directive allows you to specify how many seconds to wait before closing an idle connection. It takes the following form:

```
olcIdleTimeout: number
```

This option is disabled by default (that is, set to **0**).

Example 15.5. Using the olcIdleTimeout directive

```
olcIdleTimeout: 180
```

olcLogFile

The **olcLogFile** directive allows you to specify a file in which to write log messages. It takes the following form:

```
olcLogFile: file_name
```

The log messages are written to standard error by default.

Example 15.6. Using the olcLogFile directive

```
olcLogFile: /var/log/slapd.log
```

olcReferral

The **olcReferral** option allows you to specify a URL of a server to process the request in case the server is not able to handle it. It takes the following form:

```
olcReferral: URL
```

This option is disabled by default.

Example 15.7. Using the olcReferral directive

```
olcReferral: ldap://root.openldap.org
```

olcWriteTimeout

The **olcWriteTimeout** option allows you to specify how many seconds to wait before closing a connection with an outstanding write request. It takes the following form:

```
olcWriteTimeout
```

This option is disabled by default (that is, set to **0**).

Example 15.8. Using the olcWriteTimeout directive

```
olcWriteTimeout: 180
```

15.1.3.2. Changing the Database-Specific Configuration

By default, the OpenLDAP server uses Berkeley DB (BDB) as a database back end. The configuration for this database is stored in the **/etc/openldap/slapd.d/cn=config/olcDatabase={1}bdb.ldif** file. The following directives are commonly used in a database-specific configuration:

olcReadOnly

The **olcReadOnly** directive allows you to use the database in a read-only mode. It takes the following form:

```
olcReadOnly: boolean
```

It accepts either **TRUE** (enable the read-only mode), or **FALSE** (enable modifications of the database). The default option is **FALSE**.

Example 15.9. Using the olcReadOnly directive

```
olcReadOnly: TRUE
```

olcRootDN

The **olcRootDN** directive allows you to specify the user that is unrestricted by access controls or administrative limit parameters set for operations on the LDAP directory. It takes the following form:

```
olcRootDN: distinguished_name
```

It accepts a *Distinguished Name* (DN). The default option is **cn=Manager,dn=my-domain,dc=com**.

Example 15.10. Using the olcRootDN directive

```
olcRootDN: cn=root,dn=example,dn=com
```

olcRootPW

The **olcRootPW** directive allows you to set a password for the user that is specified using the **olcRootDN** directive. It takes the following form:

```
olcRootPW: password
```

It accepts either a plain text string, or a hash. To generate a hash, use the **slappaswd** utility, for example:

```
~]$ slappaswd
New password:
```

```
Re-enter new password:
{SSHA}WczWsyPEnMchFf1GRTweq2q7XJcvmSxD
```

Example 15.11. Using the olcRootPW directive

```
olcRootPW: {SSHA}WczWsyPEnMchFf1GRTweq2q7XJcvmSxD
```

olcSuffix

The **olcSuffix** directive allows you to specify the domain for which to provide information. It takes the following form:

```
olcSuffix: domain_name
```

It accepts a *fully qualified domain name* (FQDN). The default option is **dc=my-domain,dc=com**.

Example 15.12. Using the olcSuffix directive

```
olcSuffix: dc=example,dc=com
```

15.1.3.3. Extending Schema

Since OpenLDAP 2.3, the **/etc/openldap/slapd.d/** directory also contains LDAP definitions that were previously located in **/etc/openldap/schema/**. It is possible to extend the schema used by OpenLDAP to support additional attribute types and object classes using the default schema files as a guide. However, this task is beyond the scope of this chapter. For more information on this topic, refer to *http://www.openldap.org/doc/admin/schema.html*.

15.1.4. Running an OpenLDAP Server

This section describes how to start, stop, restart, and check the current status of the **Standalone LDAP Daemon**. For more information on how to manage system services in general, refer to *Chapter 8, Services and Daemons*.

15.1.4.1. Starting the Service

To run the `slapd` service, type the following at a shell prompt as `root`:

```
systemctl start slapd.service
```

If you want the service to start automatically at the boot time, use the following command:

```
systemctl enable slapd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

15.1.4.2. Stopping the Service

To stop the running `slapd` service, type the following at a shell prompt as `root`:

```
systemctl stop slapd.service
```

To prevent the service from starting automatically at the boot time, type:

```
systemctl disable slapd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

15.1.4.3. Restarting the Service

To restart the running `slapd` service, type the following at a shell prompt as `root`:

```
systemctl restart slapd.service
```

This stops the service, and then starts it again. Use this command to reload the configuration.

15.1.4.4. Checking the Service Status

To check whether the service is running, type the following at a shell prompt:

```
systemctl is-active slapd.service
```

15.1.5. Configuring a System to Authenticate Using OpenLDAP

In order to configure a system to authenticate using OpenLDAP, make sure that the appropriate packages are installed on both LDAP server and client machines. For information on how to set up the server, follow the instructions in *Section 15.1.2, "Installing the OpenLDAP Suite"* and *Section 15.1.3, "Configuring an OpenLDAP Server"*. On a client, type the following at a shell prompt as `root`:

```
yum install openldap openldap-clients nss-pam-ldapd
```

Chapter 9, Configuring Authentication provides detailed instructions on how to configure applications to use LDAP for authentication.

15.1.5.1. Migrating Old Authentication Information to LDAP Format

The *migrationtools* package provides a set of shell and Perl scripts to help you migrate authentication information into an LDAP format. To install this package, type the following at a shell prompt as `root`:

```
yum install migrationtools
```

This will install the scripts to the **/usr/share/migrationtools/** directory. Once installed, edit the **/usr/share/migrationtools/migrate_common.ph** file and change the following lines to reflect the correct domain, for example:

```
# Default DNS domain
```

```
$DEFAULT_MAIL_DOMAIN = "example.com";

# Default base
$DEFAULT_BASE = "dc=example,dc=com";
```

Alternatively, you can specify the environment variables directly on the command line. For example, to run the **migrate_all_online.sh** script with the default base set to **dc=example,dc=com**, type:

```
export DEFAULT_BASE="dc=example,dc=com" \
/usr/share/migrationtools/migrate_all_online.sh
```

To decide which script to run in order to migrate the user database, refer to *Table 15.8, "Commonly used LDAP migration scripts"*.

Table 15.8. Commonly used LDAP migration scripts

Existing Name Service	Is LDAP Running?	Script to Use
/etc flat files	yes	**migrate_all_online.sh**
/etc flat files	no	**migrate_all_offline.sh**
NetInfo	yes	**migrate_all_netinfo_online.sh**
NetInfo	no	**migrate_all_netinfo_offline.sh**
NIS (YP)	yes	**migrate_all_nis_online.sh**
NIS (YP)	no	**migrate_all_nis_offline.sh**

For more information on how to use these scripts, refer to the **README** and the **migration-tools.txt** files in the **/usr/share/doc/migrationtools-*version*/** directory.

15.1.6. Additional Resources

The following resources offer additional information on the Lightweight Directory Access Protocol. Before configuring LDAP on your system, it is highly recommended that you review these resources, especially the *OpenLDAP Software Administrator's Guide*.

15.1.6.1. Installed Documentation

The following documentation is installed with the *openldap-servers* package:

/usr/share/doc/openldap-servers-*version*/guide.html
A copy of the *OpenLDAP Software Administrator's Guide*.

/usr/share/doc/openldap-servers-*version*/README.schema
A README file containing the description of installed schema files.

Additionally, there is also a number of manual pages that are installed with the *openldap*, *openldap-servers*, and *openldap-clients* packages:

Client Applications

- **man ldapadd** — Describes how to add entries to an LDAP directory.
- **man ldapdelete** — Describes how to delete entries within an LDAP directory.
- **man ldapmodify** — Describes how to modify entries within an LDAP directory.
- **man ldapsearch** — Describes how to search for entries within an LDAP directory.

- **man ldappasswd** — Describes how to set or change the password of an LDAP user.
- **man ldapcompare** — Describes how to use the **ldapcompare** tool.
- **man ldapwhoami** — Describes how to use the **ldapwhoami** tool.
- **man ldapmodrdn** — Describes how to modify the RDNs of entries.

Server Applications

- **man slapd** — Describes command line options for the LDAP server.

Administrative Applications

- **man slapadd** — Describes command line options used to add entries to a **slapd** database.
- **man slapcat** — Describes command line options used to generate an LDIF file from a **slapd** database.
- **man slapindex** — Describes command line options used to regenerate an index based upon the contents of a **slapd** database.
- **man slappasswd** — Describes command line options used to generate user passwords for LDAP directories.

Configuration Files

- **man ldap.conf** — Describes the format and options available within the configuration file for LDAP clients.
- **man slapd-config** — Describes the format and options available within the configuration directory.

15.1.6.2. Useful Websites

http://www.openldap.org/doc/admin24/
: The current version of the *OpenLDAP Software Administrator's Guide*.

http://www.kingsmountain.com/ldapRoadmap.shtml
: Jeff Hodges' *LDAP Roadmap & FAQ* containing links to several useful resources and emerging news concerning the LDAP protocol.

http://www.ldapman.org/articles/
: A collection of articles that offer a good introduction to LDAP, including methods to design a directory tree and customizing directory structures.

http://www.padl.com/
: A website of developers of several useful LDAP tools.

15.1.6.3. Related Books

OpenLDAP by Example by John Terpstra and Benjamin Coles; Prentice Hall.
: A collection of practical exercises in the OpenLDAP deployment.

Implementing LDAP by Mark Wilcox; Wrox Press, Inc.
: A book covering LDAP from both the system administrator's and software developer's perspective.

Understanding and Deploying LDAP Directory Services by Tim Howes et al.; Macmillan Technical Publishing.
: A book covering LDAP design principles, as well as its deployment in a production environment.

File and Print Servers

This chapter guides you through the installation and configuration of **Samba**, an open source implementation of the *Server Message Block* (SMB) protocol, and **vsftpd**, the primary FTP server shipped with Fedora. Additionally, it explains how to use the **Printer Configuration** tool to configure printers.

16.1. Samba

Samba is an open source implementation of the *Server Message Block* (SMB) protocol. It allows the networking of Microsoft Windows®, Linux, UNIX, and other operating systems together, enabling access to Windows-based file and printer shares. Samba's use of SMB allows it to appear as a Windows server to Windows clients.



Installing the samba package

In order to use **Samba**, first ensure the *samba* package is installed on your system by running, as `root`:

```
yum install samba
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

16.1.1. Introduction to Samba

The third major release of Samba, version 3.0.0, introduced numerous improvements from prior versions, including:

- The ability to join an Active Directory domain by means of the *Lightweight Directory Access Protocol* (LDAP) and *Kerberos*
- Built in Unicode support for internationalization
- Support for all recent Microsoft Windows server and client versions to connect to Samba servers without needing local registry hacking
- Two new documents developed by the Samba.org team, which include a 400+ page reference manual, and a 300+ page implementation and integration manual. For more information about these published titles, refer to *Section 16.1.12.2, "Related Books"*.

16.1.1.1. Samba Features

Samba is a powerful and versatile server application. Even seasoned system administrators must know its abilities and limitations before attempting installation and configuration.

What Samba can do:

- Serve directory trees and printers to Linux, UNIX, and Windows clients

- Assist in network browsing (with or without NetBIOS)
- Authenticate Windows domain logins
- Provide *Windows Internet Name Service* (`WINS`) name server resolution
- Act as a Windows NT®-style *Primary Domain Controller* (PDC)
- Act as a *Backup Domain Controller* (BDC) for a Samba-based PDC
- Act as an Active Directory domain member server
- Join a Windows NT/2000/2003/2008 PDC

What Samba cannot do:

- Act as a BDC for a Windows PDC (and vice versa)
- Act as an Active Directory domain controller

16.1.2. Samba Daemons and Related Services

The following is a brief introduction to the individual Samba daemons and services.

16.1.2.1. Samba Daemons

Samba is comprised of three daemons (**`smbd`**, **`nmbd`**, and **`winbindd`**). Three services (**`smb`**, **`nmb`**, and **`winbind`**) control how the daemons are started, stopped, and other service-related features. These services act as different init scripts. Each daemon is listed in detail below, as well as which specific service has control over it.

`smbd`

The **`smbd`** server daemon provides file sharing and printing services to Windows clients. In addition, it is responsible for user authentication, resource locking, and data sharing through the `SMB` protocol. The default ports on which the server listens for `SMB` traffic are `TCP` ports `139` and `445`.

The **`smbd`** daemon is controlled by the **`smb`** service.

`nmbd`

The **`nmbd`** server daemon understands and replies to NetBIOS name service requests such as those produced by SMB/*Common Internet File System* (CIFS) in Windows-based systems. These systems include Windows 95/98/ME, Windows NT, Windows 2000, Windows XP, and LanManager clients. It also participates in the browsing protocols that make up the Windows **Network Neighborhood** view. The default port that the server listens to for `NMB` traffic is `UDP` port `137`.

The **`nmbd`** daemon is controlled by the **`nmb`** service.

`winbindd`

The **`winbind`** service resolves user and group information on a server running Windows NT, 2000, 2003 or Windows Server 2008. This makes Windows user / group information understandable by

UNIX platforms. This is achieved by using Microsoft RPC calls, *Pluggable Authentication Modules* (PAM), and the *Name Service Switch* (NSS). This allows Windows NT domain users to appear and operate as UNIX users on a UNIX machine. Though bundled with the Samba distribution, the **winbind** service is controlled separately from the **smb** service.

The **winbindd** daemon is controlled by the **winbind** service and does not require the **smb** service to be started in order to operate. **winbindd** is also used when Samba is an Active Directory member, and may also be used on a Samba domain controller (to implement nested groups and/or interdomain trust). Because **winbind** is a client-side service used to connect to Windows NT-based servers, further discussion of **winbind** is beyond the scope of this chapter.

Obtaining a list of utilities that are shipped with Samba

You may refer to *Section 16.1.11, "Samba Distribution Programs"* for a list of utilities included in the Samba distribution.

16.1.3. Connecting to a Samba Share

You can use **Nautilus** to view available Samba shares on your network. To view a list of Samba workgroups and domains on your network, select **Applications** **Accessories** **Files** from the **Activities** menu, and click **Browse Network** at the sidebar.

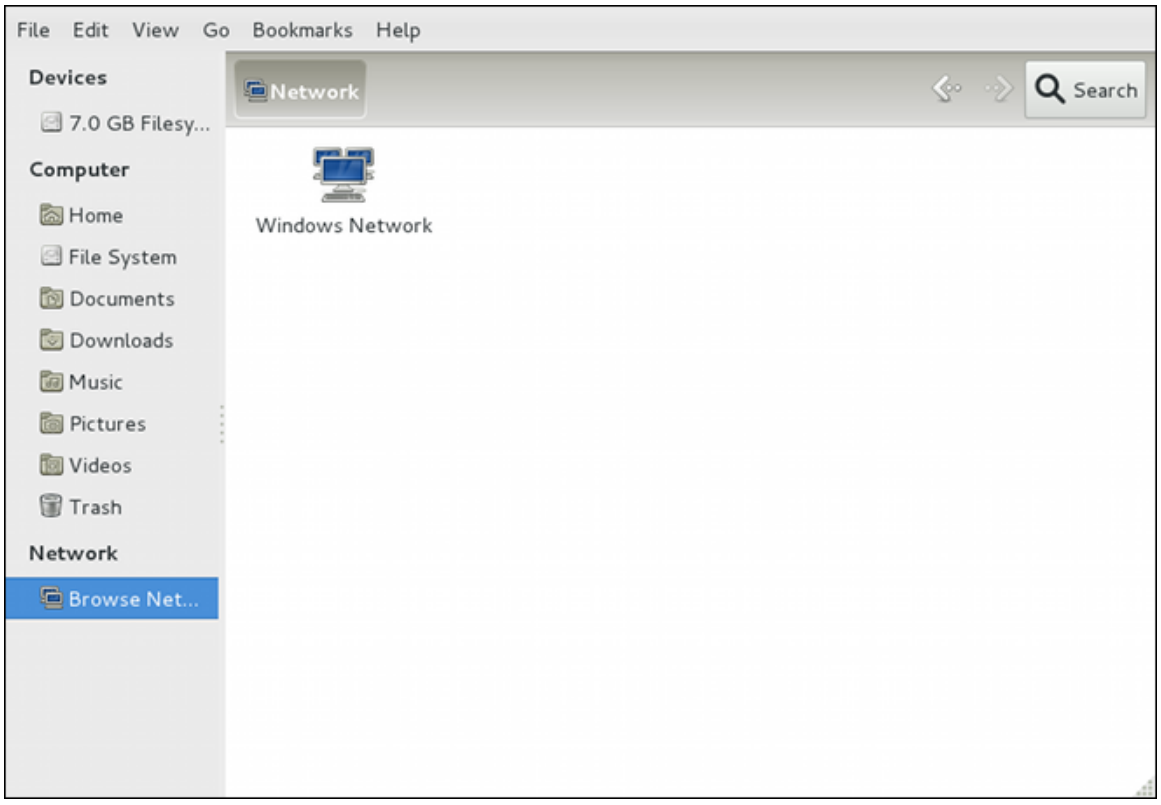


Figure 16.1. Browsing a network in Nautilus

An icon appears for each available SMB workgroup or domain on the network. Double-click one of the workgroup/domain icons to view a list of computers within the workgroup/domain.

Each machine within the workgroup is represented by its own icon. Double-click on an icon to view the Samba shares on the machine. If a username and password combination is required, you are prompted for them.

Alternately, you can also specify the Samba server and sharename in the **Location:** bar for **Nautilus** using the following syntax (replace *servername* and *sharename* with the appropriate values):

```
smb://servername/sharename
```

16.1.3.1. Command Line

To query the network for Samba servers, use the **findsmb** command. For each server found, it displays its IP address, NetBIOS name, workgroup name, operating system, and SMB server version.

To connect to a Samba share from a shell prompt, type the following command:

```
smbclient //hostname/sharename -U username
```

Replace *hostname* with the hostname or IP address of the Samba server you want to connect to, *sharename* with the name of the shared directory you want to browse, and *username* with the Samba username for the system. Enter the correct password or press **Enter** if no password is required for the user.

If you see the smb:\> prompt, you have successfully logged in. Once you are logged in, type **help** for a list of commands. If you wish to browse the contents of your home directory, replace *sharename* with your username. If the **-U** switch is not used, the username of the current user is passed to the Samba server.

To exit **smbclient**, type **exit** at the smb:\> prompt.

16.1.3.2. Mounting the Share

Sometimes it is useful to mount a Samba share to a directory so that the files in the directory can be treated as if they are part of the local file system.

To mount a Samba share to a directory, create a directory to mount it to (if it does not already exist), and execute the following command as root:

```
mount -t cifs //servername/sharename /mnt/point/ -o username=username,password=password
```

This command mounts *sharename* from *servername* in the local directory */mnt/point/*.



Installing cifs-utils package

The **mount.cifs** utility is a separate RPM (independent from Samba). In order to use **mount.cifs**, first ensure the *cifs-utils* package is installed on your system by running, as `root`:

```
yum install cifs-utils
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

Note that the *cifs-utils* package also contains the **cifs.upcall** binary called by the kernel in order to perform kerberized CIFS mounts. For more information on **cifs.upcall**, refer to **man cifs.upcall**.

For more information about mounting a samba share, refer to **man mount.cifs**.



CIFS servers that require plain text passwords

Some CIFS servers require plain text passwords for authentication. Support for plain text password authentication can be enabled using the following command as `root`:

```
echo 0x37 > /proc/fs/cifs/SecurityFlags
```

WARNING: This operation can expose passwords by removing password encryption.

16.1.4. Configuring a Samba Server

The default configuration file (**/etc/samba/smb.conf**) allows users to view their home directories as a Samba share. It also shares all printers configured for the system as Samba shared printers. In other words, you can attach a printer to the system and print to it from the Windows machines on your network.

16.1.4.1. Graphical Configuration

To configure Samba using a graphical interface, use one of the available Samba graphical user interfaces. A list of available GUIs can be found at *http://www.samba.org/samba/GUI/*.

16.1.4.2. Command Line Configuration

Samba uses **/etc/samba/smb.conf** as its configuration file. If you change this configuration file, the changes do not take effect until you restart the Samba daemon with the following command, as `root`:

```
systemctl restart smb.service
```

To specify the Windows workgroup and a brief description of the Samba server, edit the following lines in your **/etc/samba/smb.conf** file:

```
workgroup = WORKGROUPNAME
server string = BRIEF COMMENT ABOUT SERVER
```

Replace *WORKGROUPNAME* with the name of the Windows workgroup to which this machine should belong. The *BRIEF COMMENT ABOUT SERVER* is optional and is used as the Windows comment about the Samba system.

To create a Samba share directory on your Linux system, add the following section to your **/etc/samba/smb.conf** file (after modifying it to reflect your needs and your system):

```
[sharename]
comment = Insert a comment here
path = /home/share/
valid users = tfox carole
public = no
writable = yes
printable = no
create mask = 0765
```

The above example allows the users **tfox** and **carole** to read and write to the directory **/home/share**, on the Samba server, from a Samba client.

16.1.4.3. Encrypted Passwords

Encrypted passwords are enabled by default because it is more secure to do so. To create a user with an encrypted password, use the command **smbpasswd -a *username*** .

16.1.5. Starting and Stopping Samba

To start a Samba server, type the following command in a shell prompt, as `root`:

```
systemctl start smb.service
```



Setting up a domain member server

To set up a domain member server, you must first join the domain or Active Directory using the **net join** command *before* starting the **smb** service.

To stop the server, type the following command in a shell prompt, as `root`:

```
systemctl stop smb.service
```

The **restart** option is a quick way of stopping and then starting Samba. This is the most reliable way to make configuration changes take effect after editing the configuration file for Samba. Note that the restart option starts the daemon even if it was not running originally.

To restart the server, type the following command in a shell prompt, as `root`:

```
systemctl restart smb.service
```

The **condrestart** (*conditional restart*) option only starts **smb** on the condition that it is currently running. This option is useful for scripts, because it does not start the daemon if it is not running.



Applying the changes to the configuration

When the **/etc/samba/smb.conf** file is changed, Samba automatically reloads it after a few minutes. Issuing a manual **restart** or **reload** is just as effective.

To conditionally restart the server, type the following command, as `root`:

```
systemctl condrestart smb.service
```

A manual reload of the **/etc/samba/smb.conf** file can be useful in case of a failed automatic reload by the **smb** service. To ensure that the Samba server configuration file is reloaded without restarting the service, type the following command, as `root`:

```
systemctl reload smb.service
```

By default, the **smb** service does *not* start automatically at boot time. To configure Samba to start at boot time, use a service manager such as **systemctl**. Refer to *Chapter 8, Services and Daemons* for more information regarding this tool.

16.1.6. Samba Server Types and the `smb.conf` File

Samba configuration is straightforward. All modifications to Samba are done in the **/etc/samba/smb.conf** configuration file. Although the default **smb.conf** file is well documented, it does not address complex topics such as LDAP, Active Directory, and the numerous domain controller implementations.

The following sections describe the different ways a Samba server can be configured. Keep in mind your needs and the changes required to the **/etc/samba/smb.conf** file for a successful configuration.

16.1.6.1. Stand-alone Server

A stand-alone server can be a workgroup server or a member of a workgroup environment. A stand-alone server is not a domain controller and does not participate in a domain in any way. The following examples include several anonymous share-level security configurations and one user-level security configuration. For more information on share-level and user-level security modes, refer to *Section 16.1.7, “Samba Security Modes”*.

16.1.6.1.1. Anonymous Read-Only

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement anonymous read-only file sharing. The **security = share** parameter makes a share anonymous.

Note, security levels for a single Samba server cannot be mixed. The **security** directive is a global Samba parameter located in the **[global]** configuration section of the **/etc/samba/smb.conf** file.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
[data]
comment = Documentation Samba Server
path = /export
read only = Yes
guest only = Yes
```

16.1.6.1.2. Anonymous Read/Write

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement anonymous read/write file sharing. To enable anonymous read/write file sharing, set the **read only** directive to **no**. The **force user** and **force group** directives are also added to enforce the ownership of any newly placed files specified in the share.



Do not use anonymous read/write servers

Although having an anonymous read/write server is possible, it is not recommended. Any files placed in the share space, regardless of user, are assigned the user/group combination as specified by a generic user (**force user**) and group (**force group**) in the **/etc/samba/smb.conf** file.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = share
[data]
comment = Data
path = /export
force user = docsbot
force group = users
read only = No
guest ok = Yes
```

16.1.6.1.3. Anonymous Print Server

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement an anonymous print server. Setting **browseable** to **no** as shown does not list the printer in Windows **Network Neighborhood**. Although hidden from browsing, configuring the printer explicitly is possible. By connecting to **DOCS_SRV** using NetBIOS, the client can have access to the printer if the client is also part of the **DOCS** workgroup. It is also assumed that the client has the correct local printer driver installed, as the **use client driver** directive is set to **Yes**. In this case, the Samba server has no responsibility for sharing printer drivers to the client.

```
[global]
workgroup = DOCS
```

```
netbios name = DOCS_SRV
security = share
printcap name = cups
disable spools= Yes
show add printer wizard = No
printing = cups
[printers]
comment = All Printers
path = /var/spool/samba
guest ok = Yes
printable = Yes
use client driver = Yes
browseable = Yes
```

16.1.6.1.4. Secure Read/Write File and Print Server

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement a secure read/write print server. Setting the **security** directive to **user** forces Samba to authenticate client connections. Notice the **[homes]** share does not have a **force user** or **force group** directive as the **[public]** share does. The **[homes]** share uses the authenticated user details for any files created as opposed to the **force user** and **force group** in **[public]**.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = user
printcap name = cups
disable spools = Yes
show add printer wizard = No
printing = cups
[homes]
comment = Home Directories
valid users = %S
read only = No
browseable = No
[public]
comment = Data
path = /export
force user = docsbot
force group = users
guest ok = Yes
[printers]
comment = All Printers
path = /var/spool/samba
printer admin = john, ed, @admins
create mask = 0600
guest ok = Yes
printable = Yes
use client driver = Yes
browseable = Yes
```

16.1.6.2. Domain Member Server

A domain member, while similar to a stand-alone server, is logged into a domain controller (either Windows or Samba) and is subject to the domain's security rules. An example of a domain member server would be a departmental server running Samba that has a machine account on the Primary Domain Controller (PDC). All of the department's clients still authenticate with the PDC, and desktop profiles and all network policy files are included. The difference is that the departmental server has the ability to control printer and network shares.

16.1.6.2.1. Active Directory Domain Member Server

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement an Active Directory domain member server. In this example, Samba authenticates users for services being run locally but is also a client of the Active Directory. Ensure that your kerberos **realm** parameter is shown in all caps (for example **realm = EXAMPLE.COM**). Since Windows 2000/2003/2008 requires Kerberos for Active Directory authentication, the **realm** directive is required. If Active Directory and Kerberos are running on different servers, the **password server** directive may be required to help the distinction.

```
[global]
realm = EXAMPLE.COM
security = ADS
encrypt passwords = yes
# Optional. Use only if Samba cannot determine the Kerberos server automatically.
password server = kerberos.example.com
```

In order to join a member server to an Active Directory domain, the following steps must be completed:

- Configuration of the **/etc/samba/smb.conf** file on the member server
- Configuration of Kerberos, including the **/etc/krb5.conf** file, on the member server
- Creation of the machine account on the Active Directory domain server
- Association of the member server to the Active Directory domain

To create the machine account and join the Windows 2000/2003/2008 Active Directory, Kerberos must first be initialized for the member server wishing to join the Active Directory domain. To create an administrative Kerberos ticket, type the following command as `root` on the member server:

```
kinit administrator@EXAMPLE.COM
```

The **kinit** command is a Kerberos initialization script that references the Active Directory administrator account and Kerberos realm. Since Active Directory requires Kerberos tickets, **kinit** obtains and caches a Kerberos ticket-granting ticket for client/server authentication. For more information on Kerberos, the **/etc/krb5.conf** file, and the **kinit** command, refer to the *Using Kerberos* section of the Red Hat Enterprise Linux 6 *Managing Single Sign-On and Smart Cards* guide.

To join an Active Directory server (windows1.example.com), type the following command as `root` on the member server:

```
net ads join -S windows1.example.com -U administrator%password
```

Since the machine **windows1** was automatically found in the corresponding Kerberos realm (the **kinit** command succeeded), the **net** command connects to the Active Directory server using its required administrator account and password. This creates the appropriate machine account on the Active Directory and grants permissions to the Samba domain member server to join the domain.



The security option

Since **security = ads** and not **security = user** is used, a local password back end such as **smbpasswd** is not needed. Older clients that do not support **security = ads** are authenticated as if **security = domain** had been set. This change does not affect functionality and allows local users not previously in the domain.

16.1.6.2.2. Windows NT4-based Domain Member Server

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement a Windows NT4-based domain member server. Becoming a member server of an NT4-based domain is similar to connecting to an Active Directory. The main difference is NT4-based domains do not use Kerberos in their authentication method, making the **/etc/samba/smb.conf** file simpler. In this instance, the Samba member server functions as a pass through to the NT4-based domain server.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
security = domain
[homes]
comment = Home Directories
valid users = %S
read only = No
browseable = No
[public]
comment = Data
path = /export
force user = docsbot
force group = users
guest ok = Yes
```

Having Samba as a domain member server can be useful in many situations. There are times where the Samba server can have other uses besides file and printer sharing. It may be beneficial to make Samba a domain member server in instances where Linux-only applications are required for use in the domain environment. Administrators appreciate keeping track of all machines in the domain, even if not Windows-based. In the event the Windows-based server hardware is deprecated, it is quite easy to modify the **/etc/samba/smb.conf** file to convert the server to a Samba-based PDC. If Windows NT-based servers are upgraded to Windows 2000/2003/2008, the **/etc/samba/smb.conf** file is easily modifiable to incorporate the infrastructure change to Active Directory if needed.



Make sure you join the domain before starting Samba

After configuring the **/etc/samba/smb.conf** file, join the domain *before* starting Samba by typing the following command as `root`:

```
net rpc join -U administrator%password
```

Note that the **-S** option, which specifies the domain server hostname, does not need to be stated in the **net rpc join** command. Samba uses the hostname specified by the **workgroup** directive in the **/etc/samba/smb.conf** file instead of it being stated explicitly.

16.1.6.3. Domain Controller

A domain controller in Windows NT is functionally similar to a Network Information Service (NIS) server in a Linux environment. Domain controllers and NIS servers both host user/group information databases as well as related services. Domain controllers are mainly used for security, including the authentication of users accessing domain resources. The service that maintains the user/group database integrity is called the *Security Account Manager* (SAM). The SAM database is stored differently between Windows and Linux Samba-based systems, therefore SAM replication cannot be achieved and platforms cannot be mixed in a PDC/BDC environment.

In a Samba environment, there can be only one PDC and zero or more BDCs.



A mixed Samba/Windows domain controller environment

Samba cannot exist in a mixed Samba/Windows domain controller environment (Samba cannot be a BDC of a Windows PDC or vice versa). Alternatively, Samba PDCs and BDCs *can* coexist.

16.1.6.3.1. Primary Domain Controller (PDC) using tdbsam

The simplest and most common implementation of a Samba PDC uses the new default **tdbsam** password database back end. Replacing the aging **smbpasswd** back end, **tdbsam** has numerous improvements that are explained in more detail in *Section 16.1.8, "Samba Account Information Databases"*. The **passdb backend** directive controls which back end is to be used for the PDC.

The following **/etc/samba/smb.conf** file shows a sample configuration needed to implement a **tdbsam** password database back end.

```
[global]
workgroup = DOCS
netbios name = DOCS_SRV
passdb backend = tdbsam
security = user
add user script = /usr/sbin/useradd -m "%u"
delete user script = /usr/sbin/userdel -r "%u"
add group script = /usr/sbin/groupadd "%g"
delete group script = /usr/sbin/groupdel "%g"
add user to group script = /usr/sbin/usermod -G "%g" "%u"
add machine script = /usr/sbin/useradd -s /bin/false -d /dev/null  -g machines "%u"
# The following specifies the default logon script
# Per user logon scripts can be specified in the user
# account using pdbedit logon script = logon.bat
# This sets the default profile path.
# Set per user paths with pdbedit
logon drive = H:
domain logons = Yes
os level = 35
preferred master = Yes
domain master = Yes
[homes]
 comment = Home Directories
```

```
 valid users = %S
 read only = No
[netlogon]
 comment = Network Logon Service
 path = /var/lib/samba/netlogon/scripts
 browseable = No
 read only = No
# For profiles to work, create a user directory under the
# path shown.
mkdir -p /var/lib/samba/profiles/john
[Profiles]
 comment = Roaming Profile Share
 path = /var/lib/samba/profiles
 read only = No
 browseable = No
 guest ok = Yes
 profile acls = Yes
# Other resource shares ... ...
```

To provide a functional PDC system which uses the **tdbsam** follow these steps:

1. Use a configuration of the **smb.conf** file as shown in the example above.
2. Add the `root` user to the Samba password database:

   ```
   smbpasswd -a root
   ```

3. Start the **smb** service.
4. Make sure all profile, user, and netlogon directories are created.
5. Add groups that users can be members of:

   ```
   groupadd -f users
   groupadd -f nobody
   groupadd -f ntadmins
   ```

6. Associate the UNIX groups with their respective Windows groups:

   ```
   net groupmap add ntgroup="Domain Users" unixgroup=users
   net groupmap add ntgroup="Domain Guests" unixgroup=nobody
   net groupmap add ntgroup="Domain Admins" unixgroup=ntadmins
   ```

7. Grant access rights to a user or a group. For example, to grant the right to add client machines to the domain on a Samba domain controller, to the members to the Domain Admins group, execute the following command:

   ```
   net rpc rights grant 'DOCS\Domain Admins' SetMachineAccountPrivilege -S PDC -U root
   ```

Keep in mind that Windows systems prefer to have a primary group which is mapped to a domain group such as Domain Users.

Windows groups and users use the same namespace thus not allowing the existence of a group and a user with the same name like in UNIX.



Limitations of the tdbsam authentication back end

If you need more than one domain controller or have more than 250 users, do *not* use a **tdbsam** authentication back end. LDAP is recommended in these cases.

16.1.6.3.2. Primary Domain Controller (PDC) with Active Directory

Although it is possible for Samba to be a member of an Active Directory, it is not possible for Samba to operate as an Active Directory domain controller.

16.1.7. Samba Security Modes

There are only two types of security modes for Samba, *share-level* and *user-level*, which are collectively known as *security levels* . Share-level security can only be implemented in one way, while user-level security can be implemented in one of four different ways. The different ways of implementing a security level are called *security modes*.

16.1.7.1. User-Level Security

User-level security is the default setting for Samba. Even if the **security = user** directive is not listed in the **/etc/samba/smb.conf** file, it is used by Samba. If the server accepts the client's username/password, the client can then mount multiple shares without specifying a password for each instance. Samba can also accept session-based username/password requests. The client maintains multiple authentication contexts by using a unique UID for each logon.

In the **/etc/samba/smb.conf** file, the **security = user** directive that sets user-level security is:

```
[GLOBAL]
...
security = user
...
```

The following sections describe other implementations of user-level security.

16.1.7.1.1. Domain Security Mode (User-Level Security)

In domain security mode, the Samba server has a machine account (domain security trust account) and causes all authentication requests to be passed through to the domain controllers. The Samba server is made into a domain member server by using the following directives in the **/etc/samba/smb.conf** file:

```
[GLOBAL]
...
security = domain
workgroup = MARKETING
...
```

16.1.7.1.2. Active Directory Security Mode (User-Level Security)

If you have an Active Directory environment, it is possible to join the domain as a native Active Directory member. Even if a security policy restricts the use of NT-compatible authentication protocols, the Samba server can join an ADS using Kerberos. Samba in Active Directory member mode can accept Kerberos tickets.

In the **/etc/samba/smb.conf** file, the following directives make Samba an Active Directory member server:

```
[GLOBAL]
...
security = ADS
realm = EXAMPLE.COM
password server = kerberos.example.com
...
```

16.1.7.1.3. Server Security Mode (User-Level Security)

Server security mode was previously used when Samba was not capable of acting as a domain member server.



Avoid using the server security mode

It is highly recommended to *not* use this mode since there are numerous security drawbacks.

In the **/etc/samba/smb.conf**, the following directives enable Samba to operate in server security mode:

```
[GLOBAL]
...
encrypt passwords = Yes
security = server
password server = "NetBIOS_of_Domain_Controller"
...
```

16.1.7.2. Share-Level Security

With share-level security, the server accepts only a password without an explicit username from the client. The server expects a password for each share, independent of the username. There have been recent reports that Microsoft Windows clients have compatibility issues with share-level security servers. Samba developers strongly discourage use of share-level security.

In the **/etc/samba/smb.conf** file, the **security = share** directive that sets share-level security is:

```
[GLOBAL]
...
security = share
...
```

16.1.8. Samba Account Information Databases

The latest release of Samba offers many new features including new password database back ends not previously available. Samba version 3.0.0 fully supports all databases used in previous versions of Samba. However, although supported, many back ends may not be suitable for production use.

The following is a list different back ends you can use with Samba. Other back ends not listed here may also be available.

Plain Text
: Plain text back ends are nothing more than the **/etc/passwd** type back ends. With a plain text back end, all usernames and passwords are sent unencrypted between the client and the Samba server. This method is very unsecure and is not recommended for use by any means. It is possible that different Windows clients connecting to the Samba server with plain text passwords cannot support such an authentication method.

smbpasswd
: A popular back end used in previous Samba packages, the **smbpasswd** back end utilizes a plain ASCII text layout that includes the MS Windows LanMan and NT account, and encrypted password information. The **smbpasswd** back end lacks the storage of the Windows NT/2000/2003 SAM extended controls. The **smbpasswd** back end is not recommended because it does not scale well or hold any Windows information, such as RIDs for NT-based groups. The **tdbsam** back end solves these issues for use in a smaller database (250 users), but is still not an enterprise-class solution.

ldapsam_compat
: The **ldapsam_compat** back end allows continued OpenLDAP support for use with upgraded versions of Samba. This option is normally used when migrating to Samba 3.0.

tdbsam
: The new default **tdbsam** password back end provides an ideal database back end for local servers, servers that do not need built-in database replication, and servers that do not require the scalability or complexity of LDAP. The **tdbsam** back end includes all of the **smbpasswd** database information as well as the previously-excluded SAM information. The inclusion of the extended SAM data allows Samba to implement the same account and system access controls as seen with Windows NT/2000/2003/2008-based systems.

  The **tdbsam** back end is recommended for 250 users at most. Larger organizations should require Active Directory or LDAP integration due to scalability and possible network infrastructure concerns.

ldapsam
: The **ldapsam** back end provides an optimal distributed account installation method for Samba. LDAP is optimal because of its ability to replicate its database to any number of servers such as the **Red Hat Directory Server** or an **OpenLDAP Server**. LDAP databases are light-weight and scalable, and as such are preferred by large enterprises. Installation and configuration of directory servers is beyond the scope of this chapter. For more information on the **Red Hat Directory Server**, refer to the *Red Hat Directory Server 8.2 Deployment Guide*. For more information on LDAP, refer to *Section 15.1, "OpenLDAP"*.

  If you are upgrading from a previous version of Samba to 3.0, note that the OpenLDAP schema file (**/usr/share/doc/samba-*version*/LDAP/samba.schema**) and the Red Hat Directory Server schema file (**/usr/share/doc/samba-*version*/LDAP/samba-schema-FDS.ldif**)

have changed. These files contain the *attribute syntax definitions* and *objectclass definitions* that the **ldapsam** back end needs in order to function properly.

As such, if you are using the **ldapsam** back end for your Samba server, you will need to configure **slapd** to include one of these schema file. Refer to *Section 15.1.3.3, "Extending Schema"* for directions on how to do this.



Make sure the openldap-server package is installed

You need to have the **openldap-server** package installed if you want to use the **ldapsam** back end.

16.1.9. Samba Network Browsing

Network browsing enables Windows and Samba servers to appear in the Windows **Network Neighborhood**. Inside the **Network Neighborhood**, icons are represented as servers and if opened, the server's shares and printers that are available are displayed.

Network browsing capabilities require NetBIOS over TCP/IP. NetBIOS-based networking uses broadcast (UDP) messaging to accomplish browse list management. Without NetBIOS and WINS as the primary method for TCP/IP hostname resolution, other methods such as static files (**/etc/hosts**) or DNS, must be used.

A domain master browser collates the browse lists from local master browsers on all subnets so that browsing can occur between workgroups and subnets. Also, the domain master browser should preferably be the local master browser for its own subnet.

16.1.9.1. Domain Browsing

By default, a Windows server PDC for a domain is also the domain master browser for that domain. A Samba server must *not* be set up as a domain master server in this type of situation

For subnets that do not include the Windows server PDC, a Samba server can be implemented as a local master browser. Configuring the **/etc/samba/smb.conf** file for a local master browser (or no browsing at all) in a domain controller environment is the same as workgroup configuration.

16.1.9.2. WINS (Windows Internet Name Server)

Either a Samba server or a Windows NT server can function as a WINS server. When a WINS server is used with NetBIOS enabled, UDP unicasts can be routed which allows name resolution across networks. Without a WINS server, the UDP broadcast is limited to the local subnet and therefore cannot be routed to other subnets, workgroups, or domains. If WINS replication is necessary, do not use Samba as your primary WINS server, as Samba does not currently support WINS replication.

In a mixed NT/2000/2003/2008 server and Samba environment, it is recommended that you use the Microsoft WINS capabilities. In a Samba-only environment, it is recommended that you use *only one* Samba server for WINS.

The following is an example of the **/etc/samba/smb.conf** file in which the Samba server is serving as a WINS server:

```
[global]
wins support = Yes
```

Using WINS

All servers (including Samba) should connect to a WINS server to resolve NetBIOS names. Without WINS, browsing only occurs on the local subnet. Furthermore, even if a domain-wide list is somehow obtained, hosts cannot be resolved for the client without WINS.

16.1.10. Samba with CUPS Printing Support

Samba allows client machines to share printers connected to the Samba server. In addition, Samba also allows client machines to send documents built in Linux to Windows printer shares. Although there are other printing systems that function with Fedora, CUPS (Common UNIX Print System) is the recommended printing system due to its close integration with Samba.

16.1.10.1. Simple `smb.conf` Settings

The following example shows a very basic **`/etc/samba/smb.conf`** configuration for CUPS support:

```
[global]
load printers = Yes
printing = cups
printcap name = cups
[printers]
comment = All Printers
path = /var/spool/samba
browseable = No
public = Yes
guest ok = Yes
writable = No
printable = Yes
printer admin = @ntadmins
[print$]
comment = Printer Drivers Share
path = /var/lib/samba/drivers
write list = ed, john
printer admin = ed, john
```

Other printing configurations are also possible. To add additional security and privacy for printing confidential documents, users can have their own print spooler not located in a public path. If a job fails, other users would not have access to the file.

The **`print$`** directive contains printer drivers for clients to access if not available locally. The **`print$`** directive is optional and may not be required depending on the organization.

Setting **`browseable`** to **`Yes`** enables the printer to be viewed in the Windows Network Neighborhood, provided the Samba server is set up correctly in the domain/workgroup.

16.1.11. Samba Distribution Programs

findsmb

```
findsmb subnet_broadcast_address
```

The **findsmb** program is a Perl script which reports information about SMB-aware systems on a specific subnet. If no subnet is specified the local subnet is used. Items displayed include IP address, NetBIOS name, workgroup or domain name, operating system, and version.

The following example shows the output of executing **findsmb** as any valid user on a system:

```
~]$ findsmb
IP ADDR       NETBIOS NAME  WORKGROUP/OS/VERSION
------------------------------------------------------------------
10.1.59.25    VERVE          [MYGROUP] [Unix] [Samba 3.0.0-15]
10.1.59.26    STATION22      [MYGROUP] [Unix] [Samba 3.0.2-7.FC1]
10.1.56.45    TREK          +[WORKGROUP] [Windows 5.0] [Windows 2000 LAN Manager]
10.1.57.94    PIXEL          [MYGROUP] [Unix] [Samba 3.0.0-15]
10.1.57.137   MOBILE001      [WORKGROUP] [Windows 5.0] [Windows 2000 LAN Manager]
10.1.57.141   JAWS          +[KWIKIMART] [Unix] [Samba 2.2.7a-security-rollup-fix]
10.1.56.159   FRED          +[MYGROUP] [Unix] [Samba 3.0.0-14.3E]
10.1.59.192   LEGION        *[MYGROUP] [Unix] [Samba 2.2.7-security-rollup-fix]
10.1.56.205   NANCYN        +[MYGROUP] [Unix] [Samba 2.2.7a-security-rollup-fix]
```

net

```
net protocol function misc_options target_options
```

The **net** utility is similar to the **net** utility used for Windows and MS-DOS. The first argument is used to specify the protocol to use when executing a command. The ***protocol*** option can be **ads**, **rap**, or **rpc** for specifying the type of server connection. Active Directory uses **ads**, Win9x/NT3 uses **rap**, and Windows NT4/2000/2003/2008 uses **rpc**. If the protocol is omitted, **net** automatically tries to determine it.

The following example displays a list the available shares for a host named **wakko**:

```
~]$ net -l share -S wakko
Password:
Enumerating shared resources (exports) on remote server:
Share name   Type     Description
----------   ----     -----------
data         Disk     Wakko data share
tmp          Disk     Wakko tmp share
IPC$         IPC      IPC Service (Samba Server)
ADMIN$       IPC      IPC Service (Samba Server)
```

The following example displays a list of Samba users for a host named **wakko**:

```
~]$ net -l user -S wakko
root password:
User name             Comment
-----------------------------
andriusb              Documentation
joe                   Marketing
lisa                  Sales
```

nmblookup

```
nmblookup options netbios_name
```

The **nmblookup** program resolves NetBIOS names into IP addresses. The program broadcasts its query on the local subnet until the target machine replies.

Here is an example:

```
~]$ nmblookup trek
querying trek on 10.1.59.255
10.1.56.45 trek<00>
```

pdbedit

```
pdbedit options
```

The **pdbedit** program manages accounts located in the SAM database. All back ends are supported including **smbpasswd**, LDAP, and the **tdb** database library.

The following are examples of adding, deleting, and listing users:

```
~]$ pdbedit -a kristin
new password:
retype new password:
Unix username:        kristin
NT username:
Account Flags:        [U          ]
User SID:             S-1-5-21-1210235352-3804200048-1474496110-2012
Primary Group SID:    S-1-5-21-1210235352-3804200048-1474496110-2077
Full Name: Home Directory:       \\wakko\kristin
HomeDir Drive:
Logon Script:
Profile Path:         \\wakko\kristin\profile
Domain:               WAKKO
Account desc:
Workstations: Munged
dial:
Logon time:           0
Logoff time:          Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time:         Mon, 18 Jan 2038 22:14:07 GMT
Password last set:    Thu, 29 Jan 2004 08:29:28
GMT Password can change:  Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
~]$ pdbedit -v -L kristin
Unix username:        kristin
NT username:
Account Flags:        [U          ]
User SID:             S-1-5-21-1210235352-3804200048-1474496110-2012
Primary Group SID:    S-1-5-21-1210235352-3804200048-1474496110-2077
Full Name:
Home Directory:       \\wakko\kristin
HomeDir Drive:
Logon Script:
Profile Path:         \\wakko\kristin\profile
Domain:               WAKKO
```

```
Account desc:
Workstations: Munged
dial:
Logon time:           0
Logoff time:          Mon, 18 Jan 2038 22:14:07 GMT
Kickoff time:         Mon, 18 Jan 2038 22:14:07 GMT
Password last set:    Thu, 29 Jan 2004 08:29:28 GMT
Password can change:  Thu, 29 Jan 2004 08:29:28 GMT
Password must change: Mon, 18 Jan 2038 22:14:07 GMT
~]$ pdbedit -L
andriusb:505:
joe:503:
lisa:504:
kristin:506:
~]$ pdbedit -x joe
~]$ pdbedit -L
andriusb:505: lisa:504: kristin:506:
```

rpcclient

```
rpcclient server options
```

The **rpcclient** program issues administrative commands using Microsoft RPCs, which provide access to the Windows administration graphical user interfaces (GUIs) for systems management. This is most often used by advanced users that understand the full complexity of Microsoft RPCs.

smbcacls

```
smbcacls //server/share filename options
```

The **smbcacls** program modifies Windows ACLs on files and directories shared by a Samba server or a Windows server.

smbclient

```
smbclient //server/share password options
```

The **smbclient** program is a versatile UNIX client which provides functionality similar to **ftp**.

smbcontrol

```
smbcontrol -i options
```

```
smbcontrol options destination messagetype parameters
```

The **smbcontrol** program sends control messages to running **smbd**, **nmbd**, or **winbindd** daemons. Executing **smbcontrol -i** runs commands interactively until a blank line or a *'q'* is entered.

smbpasswd

```
smbpasswd options username password
```

The **smbpasswd** program manages encrypted passwords. This program can be run by a superuser to change any user's password as well as by an ordinary user to change their own Samba password.

smbspool

```
smbspool job user title copies options filename
```

The **smbspool** program is a CUPS-compatible printing interface to Samba. Although designed for use with CUPS printers, **smbspool** can work with non-CUPS printers as well.

smbstatus

```
smbstatus options
```

The **smbstatus** program displays the status of current connections to a Samba server.

smbtar

```
smbtar options
```

The **smbtar** program performs backup and restores of Windows-based share files and directories to a local tape archive. Though similar to the **tar** command, the two are not compatible.

testparm

```
testparm options filename hostname IP_address
```

The **testparm** program checks the syntax of the **/etc/samba/smb.conf** file. If your **/etc/samba/smb.conf** file is in the default location (**/etc/samba/smb.conf**) you do not need to specify the location. Specifying the hostname and IP address to the **testparm** program verifies that the **hosts.allow** and **host.deny** files are configured correctly. The **testparm** program also displays a summary of your **/etc/samba/smb.conf** file and the server's role (stand-alone, domain, etc.) after testing. This is convenient when debugging as it excludes comments and concisely presents information for experienced administrators to read.

For example:

```
~]$ testparm
Load smb config files from /etc/samba/smb.conf
```

```
Processing section "[homes]"
Processing section "[printers]"
Processing section "[tmp]"
Processing section "[html]"
Loaded services file OK.
Server role: ROLE_STANDALONE
Press enter to see a dump of your service definitions
<enter>
# Global parameters
[global]
 workgroup = MYGROUP
 server string = Samba Server
 security = SHARE
 log file = /var/log/samba/%m.log
 max log size = 50
 socket options = TCP_NODELAY SO_RCVBUF=8192 SO_SNDBUF=8192
 dns proxy = No
[homes]
 comment = Home Directories
 read only = No
 browseable = No
[printers]
 comment = All Printers
 path = /var/spool/samba
 printable = Yes
 browseable = No
[tmp]
 comment = Wakko tmp
 path = /tmp
 guest only = Yes
[html]
 comment = Wakko www
 path = /var/www/html
 force user = andriusb
 force group = users
 read only = No
 guest only = Yes
```

wbinfo

```
wbinfo options
```

The **wbinfo** program displays information from the **winbindd** daemon. The **winbindd** daemon must be running for **wbinfo** to work.

16.1.12. Additional Resources

The following sections give you the means to explore Samba in greater detail.

16.1.12.1. Installed Documentation

- **/usr/share/doc/samba-*version-number*/** — All additional files included with the Samba distribution. This includes all helper scripts, sample configuration files, and documentation. This directory also contains online versions of *The Official Samba-3 HOWTO-Collection* and *Samba-3 by Example*, both of which are cited below.



Make sure you have the samba-doc package installed

In order to use the **Samba** documentation, first ensure the *samba-doc* package is installed on your system by running, as `root`:

```
yum install samba-doc
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

Refer to the following manual pages for detailed information specific **Samba** features:

- **`smb.conf`**
- **`samba`**
- **`smbd`**
- **`nmbd`**
- **`winbind`**

16.1.12.2. Related Books

- *The Official Samba-3 HOWTO-Collection* by John H. Terpstra and Jelmer R. Vernooij; Prentice Hall — The official Samba-3 documentation as issued by the Samba development team. This is more of a reference guide than a step-by-step guide.
- *Samba-3 by Example* by John H. Terpstra; Prentice Hall — This is another official release issued by the Samba development team which discusses detailed examples of OpenLDAP, DNS, DHCP, and printing configuration files. This has step-by-step related information that helps in real-world implementations.
- *Using Samba, 2nd Edition* by Jay T's, Robert Eckstein, and David Collier-Brown; O'Reilly — A good resource for novice to advanced users, which includes comprehensive reference material.

16.1.12.3. Useful Websites

- *http://www.samba.org/* — Homepage for the Samba distribution and all official documentation created by the Samba development team. Many resources are available in HTML and PDF formats, while others are only available for purchase. Although many of these links are not Fedora specific, some concepts may apply.
- *http://samba.org/samba/archives.html* [1] — Active email lists for the Samba community. Enabling digest mode is recommended due to high levels of list activity.

[1] http://us1.samba.org/samba/archives.html

- Samba newsgroups — Samba threaded newsgroups, such as gmane.org, that use the NNTP protocol are also available. This an alternative to receiving mailing list emails.

16.2. FTP

File Transfer Protocol (FTP) is one of the oldest and most commonly used protocols found on the Internet today. Its purpose is to reliably transfer files between computer hosts on a network without requiring the user to log directly into the remote host or have knowledge of how to use the remote system. It allows users to access files on remote systems using a standard set of simple commands.

This section outlines the basics of the FTP protocol, as well as configuration options for the primary FTP server shipped with Fedora, **vsftpd**.

16.2.1. The File Transfer Protocol

However, because FTP is so prevalent on the Internet, it is often required to share files to the public. System administrators, therefore, should be aware of the FTP protocol's unique characteristics.

16.2.1.1. Multiple Ports, Multiple Modes

Unlike most protocols used on the Internet, FTP requires multiple network ports to work properly. When an FTP client application initiates a connection to an FTP server, it opens port 21 on the server — known as the *command port*. This port is used to issue all commands to the server. Any data requested from the server is returned to the client via a *data port*. The port number for data connections, and the way in which data connections are initialized, vary depending upon whether the client requests the data in *active* or *passive* mode.

The following defines these modes:

active mode
: Active mode is the original method used by the FTP protocol for transferring data to the client application. When an active mode data transfer is initiated by the FTP client, the server opens a connection from port 20 on the server to the IP address and a random, unprivileged port (greater than 1024) specified by the client. This arrangement means that the client machine must be allowed to accept connections over any port above 1024. With the growth of insecure networks, such as the Internet, the use of firewalls to protect client machines is now prevalent. Because these client-side firewalls often deny incoming connections from active mode FTP servers, passive mode was devised.

passive mode
: Passive mode, like active mode, is initiated by the FTP client application. When requesting data from the server, the FTP client indicates it wants to access the data in passive mode and the server provides the IP address and a random, unprivileged port (greater than 1024) on the server. The client then connects to that port on the server to download the requested information.

  While passive mode resolves issues for client-side firewall interference with data connections, it can complicate administration of the server-side firewall. You can reduce the number of open ports on a server by limiting the range of unprivileged ports on the FTP server. This also simplifies the process of configuring firewall rules for the server. Refer to *Section 16.2.5.8, “Network Options”* for more information about limiting passive ports.

16.2.2. FTP Servers

Fedora ships with two different FTP servers:

- **Red Hat Content Accelerator** — A kernel-based Web server that delivers high performance Web server and FTP services. Since speed is its primary design goal, it has limited functionality and runs only as an anonymous FTP server. For more information about configuring and administering **Red Hat Content Accelerator**, consult the documentation available online at *http://www.redhat.com/docs/manuals/tux/*.

- **vsftpd** — A fast, secure FTP daemon which is the preferred FTP server for Fedora. The remainder of this section focuses on **vsftpd**.

16.2.2.1. vsftpd

The Very Secure FTP Daemon (**vsftpd**) is designed from the ground up to be fast, stable, and, most importantly, secure. **vsftpd** is the only stand-alone FTP server distributed with Fedora, due to its ability to handle large numbers of connections efficiently and securely.

The security model used by **vsftpd** has three primary aspects:

- *Strong separation of privileged and non-privileged processes* — Separate processes handle different tasks, and each of these processes run with the minimal privileges required for the task.

- *Tasks requiring elevated privileges are handled by processes with the minimal privilege necessary* — By leveraging compatibilities found in the **libcap** library, tasks that usually require full `root` privileges can be executed more safely from a less privileged process.

- *Most processes run in a **chroot** jail* — Whenever possible, processes are change-rooted to the directory being shared; this directory is then considered a **chroot** jail. For example, if the directory **/var/ftp/** is the primary shared directory, **vsftpd** reassigns **/var/ftp/** to the new root directory, known as **/**. This disallows any potential malicious hacker activities for any directories not contained below the new root directory.

Use of these security practices has the following effect on how **vsftpd** deals with requests:

- *The parent process runs with the least privileges required* — The parent process dynamically calculates the level of privileges it requires to minimize the level of risk. Child processes handle direct interaction with the FTP clients and run with as close to no privileges as possible.

- *All operations requiring elevated privileges are handled by a small parent process* — Much like the Apache HTTP Server, **vsftpd** launches unprivileged child processes to handle incoming connections. This allows the privileged, parent process to be as small as possible and handle relatively few tasks.

- *All requests from unprivileged child processes are distrusted by the parent process* — Communication with child processes are received over a socket, and the validity of any information from child processes is checked before being acted on.

- *Most interaction with FTP clients is handled by unprivileged child processes in a **chroot** jail* — Because these child processes are unprivileged and only have access to the directory being shared, any crashed processes only allows the attacker access to the shared files.

16.2.3. Files Installed with vsftpd

The **vsftpd** RPM installs the daemon (**/usr/sbin/vsftpd**), its configuration and related files, as well as FTP directories onto the system. The following lists the files and directories related to **vsftpd** configuration:

- **/etc/rc.d/init.d/vsftpd** — The *initialization script* (*initscript*) used by the **systemctl** command to start, stop, or reload **vsftpd**. Refer to *Section 16.2.4, "Starting and Stopping **vsftpd**"* for more information about using this script.
- **/etc/pam.d/vsftpd** — The Pluggable Authentication Modules (PAM) configuration file for **vsftpd**. This file specifies the requirements a user must meet to login to the FTP server. For more information on PAM, refer to the *Using Pluggable Authentication Modules (PAM)* chapter of the Fedora 17 *Managing Single Sign-On and Smart Cards* guide.
- **/etc/vsftpd/vsftpd.conf** — The configuration file for **vsftpd**. Refer to *Section 16.2.5, "**vsftpd** Configuration Options"* for a list of important options contained within this file.
- **/etc/vsftpd/ftpusers** — A list of users not allowed to log into **vsftpd**. By default, this list includes the `root`, `bin`, and `daemon` users, among others.
- **/etc/vsftpd/user_list** — This file can be configured to either deny or allow access to the users listed, depending on whether the **userlist_deny** directive is set to **YES** (default) or **NO** in **/etc/vsftpd/vsftpd.conf**. If **/etc/vsftpd/user_list** is used to grant access to users, the usernames listed must *not* appear in **/etc/vsftpd/ftpusers**.
- **/var/ftp/** — The directory containing files served by **vsftpd**. It also contains the **/var/ftp/pub/** directory for anonymous users. Both directories are world-readable, but writable only by the `root` user.

16.2.4. Starting and Stopping `vsftpd`

The **vsftpd** RPM installs the **/etc/rc.d/init.d/vsftpd** script, which can be accessed using the **systemctl** command.

To start the server, as `root` type:

```
systemctl start vsftpd.service
```

To stop the server, as `root` type:

```
systemctl stop vsftpd.service
```

The **restart** option is a shorthand way of stopping and then starting **vsftpd**. This is the most efficient way to make configuration changes take effect after editing the configuration file for **vsftpd**.

To restart the server, as `root` type:

```
systemctl restart vsftpd.service
```

The **condrestart** (*conditional restart*) option only starts **vsftpd** if it is currently running. This option is useful for scripts, because it does not start the daemon if it is not running.

To conditionally restart the server, as `root` type:

```
systemctl condrestart vsftpd.service
```

By default, the **vsftpd** service does *not* start automatically at boot time. To configure the **vsftpd** service to start at boot time, use a service manager such as **systemctl**. Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

16.2.4.1. Starting Multiple Copies of vsftpd

Sometimes one computer is used to serve multiple FTP domains. This is a technique called *multihoming*. One way to multihome using **vsftpd** is by running multiple copies of the daemon, each with its own configuration file.

To do this, first assign all relevant IP addresses to network devices or alias network devices on the system. Additional information about network configuration scripts can be found in *Chapter 7, Network Interfaces*.

Next, the DNS server for the FTP domains must be configured to reference the correct machine. For information about BIND and its configuration files, refer to *Section 12.2, "BIND"*.

If there is more configuration files present in the **/etc/vsftpd** directory, calling **systemctl start vsftpd.service** results in the **/etc/rc.d/init.d/vsftpd** initscript starting the same number of processes as the number of configuration files. Each configuration file must have a unique name in the **/etc/vsftpd/** directory and must be readable and writable only by root.

16.2.5. vsftpd Configuration Options

Although **vsftpd** may not offer the level of customization other widely available FTP servers have, it offers enough options to fill most administrator's needs. The fact that it is not overly feature-laden limits configuration and programmatic errors.

All configuration of **vsftpd** is handled by its configuration file, **/etc/vsftpd/vsftpd.conf**. Each directive is on its own line within the file and follows the following format:

```
directive=value
```

For each directive, replace *directive* with a valid directive and *value* with a valid value.



Do not use spaces

There must not be any spaces between the *directive*, equal symbol, and the *value* in a directive.

Comment lines must be preceded by a hash sign (#) and are ignored by the daemon.

For a complete list of all directives available, refer to the man page for **vsftpd.conf**.



Securing the vsftpd service

For an overview of ways to secure **vsftpd**, refer to the Fedora 17 *Security Guide*.

The following is a list of some of the more important directives within **/etc/vsftpd/vsftpd.conf**. All directives not explicitly found or commented out within **vsftpd**'s configuration file are set to their default value.

16.2.5.1. Daemon Options

The following is a list of directives which control the overall behavior of the **vsftpd** daemon.

- **listen** — When enabled, **vsftpd** runs in stand-alone mode. Fedora sets this value to **YES**. This directive cannot be used in conjunction with the **listen_ipv6** directive.

  The default value is **NO**.

- **listen_ipv6** — When enabled, **vsftpd** runs in stand-alone mode, but listens only to IPv6 sockets. This directive cannot be used in conjunction with the **listen** directive.

  The default value is **NO**.

- **session_support** — When enabled, **vsftpd** attempts to maintain login sessions for each user through Pluggable Authentication Modules (PAM). For more information, refer to the *Using Pluggable Authentication Modules (PAM)* chapter of the Red Hat Enterprise Linux 6 *Managing Single Sign-On and Smart Cards* and the PAM man pages. . If session logging is not necessary, disabling this option allows **vsftpd** to run with less processes and lower privileges.

  The default value is **YES**.

16.2.5.2. Log In Options and Access Controls

The following is a list of directives which control the login behavior and access control mechanisms.

- **anonymous_enable** — When enabled, anonymous users are allowed to log in. The usernames **anonymous** and **ftp** are accepted.

  The default value is **YES**.

  Refer to *Section 16.2.5.3, "Anonymous User Options"* for a list of directives affecting anonymous users.

- **banned_email_file** — If the **deny_email_enable** directive is set to **YES**, this directive specifies the file containing a list of anonymous email passwords which are not permitted access to the server.

  The default value is **/etc/vsftpd/banned_emails**.

- **banner_file** — Specifies the file containing text displayed when a connection is established to the server. This option overrides any text specified in the **ftpd_banner** directive.

  There is no default value for this directive.

- **cmds_allowed** — Specifies a comma-delimited list of FTP commands allowed by the server. All other commands are rejected.

  There is no default value for this directive.

- **deny_email_enable** — When enabled, any anonymous user utilizing email passwords specified in the **/etc/vsftpd/banned_emails** are denied access to the server. The name of the file referenced by this directive can be specified using the **banned_email_file** directive.

  The default value is **NO**.

- **ftpd_banner** — When enabled, the string specified within this directive is displayed when a connection is established to the server. This option can be overridden by the **banner_file** directive.

  By default **vsftpd** displays its standard banner.

- **local_enable** — When enabled, local users are allowed to log into the system.

  The default value is **YES**.

  Refer to *Section 16.2.5.4, "Local User Options"* for a list of directives affecting local users.

- **pam_service_name** — Specifies the PAM service name for **vsftpd**.

  The default value is **ftp**. Note, in Fedora, the value is set to **vsftpd**.

- The default value is **NO**. Note, in Fedora, the value is set to **YES**.

- **userlist_deny** — When used in conjunction with the **userlist_enable** directive and set to **NO**, all local users are denied access unless the username is listed in the file specified by the **userlist_file** directive. Because access is denied before the client is asked for a password, setting this directive to **NO** prevents local users from submitting unencrypted passwords over the network.

  The default value is **YES**.

- **userlist_enable** — When enabled, the users listed in the file specified by the **userlist_file** directive are denied access. Because access is denied before the client is asked for a password, users are prevented from submitting unencrypted passwords over the network.

  The default value is **NO**, however under Fedora the value is set to **YES**.

- **userlist_file** — Specifies the file referenced by **vsftpd** when the **userlist_enable** directive is enabled.

  The default value is **/etc/vsftpd/user_list** and is created during installation.

16.2.5.3. Anonymous User Options

The following lists directives which control anonymous user access to the server. To use these options, the **anonymous_enable** directive must be set to **YES**.

- **anon_mkdir_write_enable** — When enabled in conjunction with the **write_enable** directive, anonymous users are allowed to create new directories within a parent directory which has write permissions.

  The default value is **NO**.

- **anon_root** — Specifies the directory **vsftpd** changes to after an anonymous user logs in.

  There is no default value for this directive.

- **anon_upload_enable** — When enabled in conjunction with the **write_enable** directive, anonymous users are allowed to upload files within a parent directory which has write permissions.

  The default value is **NO**.

- **anon_world_readable_only** — When enabled, anonymous users are only allowed to download world-readable files.

  The default value is **YES**.

- **ftp_username** — Specifies the local user account (listed in **/etc/passwd**) used for the anonymous FTP user. The home directory specified in **/etc/passwd** for the user is the root directory of the anonymous FTP user.

  The default value is **ftp**.

- **no_anon_password** — When enabled, the anonymous user is not asked for a password.

  The default value is **NO**.

- **secure_email_list_enable** — When enabled, only a specified list of email passwords for anonymous logins are accepted. This is a convenient way to offer limited security to public content without the need for virtual users.

  Anonymous logins are prevented unless the password provided is listed in **/etc/vsftpd/email_passwords**. The file format is one password per line, with no trailing white spaces.

  The default value is **NO**.

16.2.5.4. Local User Options

The following lists directives which characterize the way local users access the server. To use these options, the **local_enable** directive must be set to **YES**.

- **chmod_enable** — When enabled, the FTP command **SITE CHMOD** is allowed for local users. This command allows the users to change the permissions on files.

  The default value is **YES**.

- **chroot_list_enable** — When enabled, the local users listed in the file specified in the **chroot_list_file** directive are placed in a **chroot** jail upon log in.

  If enabled in conjunction with the **chroot_local_user** directive, the local users listed in the file specified in the **chroot_list_file** directive are *not* placed in a **chroot** jail upon log in.

  The default value is **NO**.

- **chroot_list_file** — Specifies the file containing a list of local users referenced when the **chroot_list_enable** directive is set to **YES**.

  The default value is **/etc/vsftpd/chroot_list**.

- **chroot_local_user** — When enabled, local users are change-rooted to their home directories after logging in.

  The default value is **NO**.



Avoid enabling the chroot_local_user option

Enabling **chroot_local_user** opens up a number of security issues, especially for users with upload privileges. For this reason, it is *not* recommended.

- **guest_enable** — When enabled, all non-anonymous users are logged in as the user **guest**, which is the local user specified in the **guest_username** directive.

  The default value is **NO**.

- **guest_username** — Specifies the username the **guest** user is mapped to.

  The default value is **ftp**.

- **local_root** — Specifies the directory **vsftpd** changes to after a local user logs in.

  There is no default value for this directive.

- **local_umask** — Specifies the umask value for file creation. Note that the default value is in octal form (a numerical system with a base of eight), which includes a "0" prefix. Otherwise the value is treated as a base-10 integer.

  The default value is **022**.

- **passwd_chroot_enable** — When enabled in conjunction with the **chroot_local_user** directive, **vsftpd** change-roots local users based on the occurrence of the **/./** in the home directory field within **/etc/passwd**.

  The default value is **NO**.

- **user_config_dir** — Specifies the path to a directory containing configuration files bearing the name of local system users that contain specific setting for that user. Any directive in the user's configuration file overrides those found in **/etc/vsftpd/vsftpd.conf**.

  There is no default value for this directive.

16.2.5.5. Directory Options

The following lists directives which affect directories.

- **dirlist_enable** — When enabled, users are allowed to view directory lists.

  The default value is **YES**.

- **dirmessage_enable** — When enabled, a message is displayed whenever a user enters a directory with a message file. This message resides within the current directory. The name of this file is specified in the **message_file** directive and is **.message** by default.

  The default value is **NO**. Note, in Fedora, the value is set to **YES**.

- **force_dot_files** — When enabled, files beginning with a dot (**.**) are listed in directory listings, with the exception of the **.** and **..** files.

The default value is **NO**.

- **hide_ids** — When enabled, all directory listings show **ftp** as the user and group for each file.

  The default value is **NO**.

- **message_file** — Specifies the name of the message file when using the **dirmessage_enable** directive.

  The default value is **.message**.

- **text_userdb_names** — When enabled, text usernames and group names are used in place of UID and GID entries. Enabling this option may slow performance of the server.

  The default value is **NO**.

- **use_localtime** — When enabled, directory listings reveal the local time for the computer instead of GMT.

  The default value is **NO**.

16.2.5.6. File Transfer Options

The following lists directives which affect directories.

- **download_enable** — When enabled, file downloads are permitted.

  The default value is **YES**.

- **chown_uploads** — When enabled, all files uploaded by anonymous users are owned by the user specified in the **chown_username** directive.

  The default value is **NO**.

- **chown_username** — Specifies the ownership of anonymously uploaded files if the **chown_uploads** directive is enabled.

  The default value is **root**.

- **write_enable** — When enabled, FTP commands which can change the file system are allowed, such as **DELE**, **RNFR**, and **STOR**.

  The default value is **YES**.

16.2.5.7. Logging Options

The following lists directives which affect **vsftpd**'s logging behavior.

- **dual_log_enable** — When enabled in conjunction with **xferlog_enable**, **vsftpd** writes two files simultaneously: a **wu-ftpd**-compatible log to the file specified in the **xferlog_file** directive (**/var/log/xferlog** by default) and a standard **vsftpd** log file specified in the **vsftpd_log_file** directive (**/var/log/vsftpd.log** by default).

  The default value is **NO**.

- **log_ftp_protocol** — When enabled in conjunction with **xferlog_enable** and with **xferlog_std_format** set to **NO**, all FTP commands and responses are logged. This directive is useful for debugging.

  The default value is **NO**.

- **syslog_enable** — When enabled in conjunction with **xferlog_enable**, all logging normally written to the standard **vsftpd** log file specified in the **vsftpd_log_file** directive (**/var/log/vsftpd.log** by default) is sent to the system logger instead under the FTPD facility.

  The default value is **NO**.

- **vsftpd_log_file** — Specifies the **vsftpd** log file. For this file to be used, **xferlog_enable** must be enabled and **xferlog_std_format** must either be set to **NO** or, if **xferlog_std_format** is set to **YES**, **dual_log_enable** must be enabled. It is important to note that if **syslog_enable** is set to **YES**, the system log is used instead of the file specified in this directive.

  The default value is **/var/log/vsftpd.log**.

- **xferlog_enable** — When enabled, **vsftpd** logs connections (**vsftpd** format only) and file transfer information to the log file specified in the **vsftpd_log_file** directive (**/var/log/vsftpd.log** by default). If **xferlog_std_format** is set to **YES**, file transfer information is logged but connections are not, and the log file specified in **xferlog_file** (**/var/log/xferlog** by default) is used instead. It is important to note that both log files and log formats are used if **dual_log_enable** is set to **YES**.

  The default value is **NO**. Note, in Fedora, the value is set to **YES**.

- **xferlog_file** — Specifies the **wu-ftpd**-compatible log file. For this file to be used, **xferlog_enable** must be enabled and **xferlog_std_format** must be set to **YES**. It is also used if **dual_log_enable** is set to **YES**.

  The default value is **/var/log/xferlog**.

- **xferlog_std_format** — When enabled in conjunction with **xferlog_enable**, only a **wu-ftpd**-compatible file transfer log is written to the file specified in the **xferlog_file** directive (**/var/log/xferlog** by default). It is important to note that this file only logs file transfers and does not log connections to the server.

  The default value is **NO**. Note, in Fedora, the value is set to **YES**.



Maintaining compatibility with older log file formats

To maintain compatibility with log files written by the older **wu-ftpd** FTP server, the **xferlog_std_format** directive is set to **YES** under Fedora. However, this setting means that connections to the server are not logged.

To both log connections in **vsftpd** format and maintain a **wu-ftpd**-compatible file transfer log, set **dual_log_enable** to **YES**.

If maintaining a **wu-ftpd**-compatible file transfer log is not important, either set **xferlog_std_format** to **NO**, comment the line with a hash sign (#), or delete the line entirely.

16.2.5.8. Network Options

The following lists directives which affect how **vsftpd** interacts with the network.

- **accept_timeout** — Specifies the amount of time for a client using passive mode to establish a connection.

  The default value is **60**.

- **anon_max_rate** — Specifies the maximum data transfer rate for anonymous users in bytes per second.

  The default value is **0**, which does not limit the transfer rate.

- **connect_from_port_20** When enabled, **vsftpd** runs with enough privileges to open port 20 on the server during active mode data transfers. Disabling this option allows **vsftpd** to run with less privileges, but may be incompatible with some FTP clients.

  The default value is **NO**. Note, in Fedora, the value is set to **YES**.

- **connect_timeout** — Specifies the maximum amount of time a client using active mode has to respond to a data connection, in seconds.

  The default value is **60**.

- **data_connection_timeout** — Specifies maximum amount of time data transfers are allowed to stall, in seconds. Once triggered, the connection to the remote client is closed.

  The default value is **300**.

- **ftp_data_port** — Specifies the port used for active data connections when **connect_from_port_20** is set to **YES**.

  The default value is **20**.

- **idle_session_timeout** — Specifies the maximum amount of time between commands from a remote client. Once triggered, the connection to the remote client is closed.

  The default value is **300**.

- **listen_address** — Specifies the IP address on which **vsftpd** listens for network connections.

  There is no default value for this directive.

  Running multiple copies of vsftpd

  If running multiple copies of **vsftpd** serving different IP addresses, the configuration file for each copy of the **vsftpd** daemon must have a different value for this directive. Refer to *Section 16.2.4.1, "Starting Multiple Copies of **vsftpd**"* for more information about multihomed FTP servers.

- **listen_address6** — Specifies the IPv6 address on which **vsftpd** listens for network connections when **listen_ipv6** is set to **YES**.

There is no default value for this directive.



Running multiple copies of vsftpd

If running multiple copies of **vsftpd** serving different IP addresses, the configuration file for each copy of the **vsftpd** daemon must have a different value for this directive. Refer to *Section 16.2.4.1, "Starting Multiple Copies of **vsftpd**"* for more information about multihomed FTP servers.

- **listen_port** — Specifies the port on which **vsftpd** listens for network connections.

  The default value is **21**.

- **local_max_rate** — Specifies the maximum rate data is transferred for local users logged into the server in bytes per second.

  The default value is **0**, which does not limit the transfer rate.

- **max_clients** — Specifies the maximum number of simultaneous clients allowed to connect to the server when it is running in standalone mode. Any additional client connections would result in an error message.

  The default value is **0**, which does not limit connections.

- **max_per_ip** — Specifies the maximum of clients allowed to connected from the same source IP address.

  The default value is **0**, which does not limit connections.

- **pasv_address** — Specifies the IP address for the public facing IP address of the server for servers behind Network Address Translation (NAT) firewalls. This enables **vsftpd** to hand out the correct return address for passive mode connections.

  There is no default value for this directive.

- **pasv_enable** — When enabled, passive mode connects are allowed.

  The default value is **YES**.

- **pasv_max_port** — Specifies the highest possible port sent to the FTP clients for passive mode connections. This setting is used to limit the port range so that firewall rules are easier to create.

  The default value is **0**, which does not limit the highest passive port range. The value must not exceed **65535**.

- **pasv_min_port** — Specifies the lowest possible port sent to the FTP clients for passive mode connections. This setting is used to limit the port range so that firewall rules are easier to create.

  The default value is **0**, which does not limit the lowest passive port range. The value must not be lower **1024**.

- **pasv_promiscuous** — When enabled, data connections are not checked to make sure they are originating from the same IP address. This setting is only useful for certain types of tunneling.



Avoid enabling the pasv_promiscuous option

Do not enable this option unless absolutely necessary as it disables an important security feature which verifies that passive mode connections originate from the same `IP` address as the control connection that initiates the data transfer.

The default value is **`NO`**.

- **`port_enable`** — When enabled, active mode connects are allowed.

  The default value is **`YES`**.

16.2.6. Additional Resources

For more information about **`vsftpd`**, refer to the following resources.

16.2.6.1. Installed Documentation

- The **`/usr/share/doc/vsftpd-`*`version-number`*`/`** directory — Replace *`version-number`* with the installed version of the **`vsftpd`** package. This directory contains a **`README`** with basic information about the software. The **`TUNING`** file contains basic performance tuning tips and the **`SECURITY/`** directory contains information about the security model employed by **`vsftpd`**.
- **`vsftpd`** related man pages — There are a number of man pages for the daemon and configuration files. The following lists some of the more important man pages.

  Server Applications
  - **`man vsftpd`** — Describes available command line options for **`vsftpd`**.

  Configuration Files
  - **`man vsftpd.conf`** — Contains a detailed list of options available within the configuration file for **`vsftpd`**.
  - **`man 5 hosts_access`** — Describes the format and options available within the TCP wrappers configuration files: **`hosts.allow`** and **`hosts.deny`**.

16.2.6.2. Useful Websites

- *http://vsftpd.beasts.org/* — The **`vsftpd`** project page is a great place to locate the latest documentation and to contact the author of the software.
- *http://slacksite.com/other/ftp.html* — This website provides a concise explanation of the differences between active and passive mode FTP.
- *http://www.ietf.org/rfc/rfc0959.txt* — The original *Request for Comments* (*RFC*) of the FTP protocol from the IETF.

16.3. Printer Configuration

The **Printer Configuration** tool serves for printer configuring, maintenance of printer configuration files, print spool directories and print filters, and printer classes management.

The tool is based on the Common Unix Printing System (CUPS). If you upgraded the system from a previous Fedora version that used CUPS, the upgrade process preserved the configured printers.

Using the CUPS web application or command line tools

You can perform the same and additional operations on printers directly from the CUPS web application or command line. To access the application, in a web browser, go to *http://localhost:631/*. For CUPS manuals refer to the links on the **Home** tab of the web site.

16.3.1. Starting the Printer Configuration Tool

With the Printer Configuration tool you can perform various operations on existing printers and set up new printers.

On the upper panel, go to **Activities**, choose **Applications** and click **Printing**. Alternatively, run the **`system-config-printer`** command from the command line to start the tool.

The **Printer Configuration** window depicted in *Figure 16.2, "Printer Configuration window"* appears.

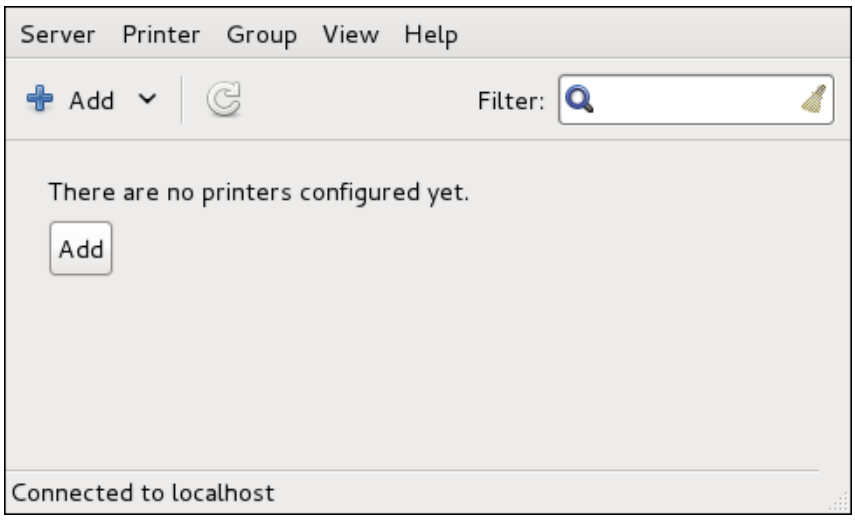


Figure 16.2. Printer Configuration window

16.3.2. Starting Printer Setup

Printer setup process varies depending on the printer queue type.

If you are setting up a local printer connected with USB, the printer is discovered and added automatically. You will be prompted to confirm the packages to be installed and provide the root password. Local printers connected with other port types and network printers need to be set up manually.

Follow this procedure to start a manual printer setup:

1. Start the Printer Configuration tool (refer to *Section 16.3.1, “Starting the Printer Configuration Tool”*).
2. Go to **Server□□□ New□□□ Printer**.
3. In the **Authentication Required** box, type the root user password and confirm.
4. Select the printer connection type and provide its details in the area on the right.

16.3.3. Adding a Local Printer

Follow this procedure to add a local printer connected with other than a serial port:

1. Open the `New Printer` dialog (refer to *Section 16.3.2, “Starting Printer Setup”*).
2. If the device does not appear automatically, select the port to which the printer is connected in the list on the left (such as **Serial Port #1** or **LPT #1**).
3. On the right, enter the connection properties:

   for **Enter URI**
   URI (for example file:/dev/lp0)

   for **Serial Port**
   Baud Rate

   Parity

   Data Bits

   Flow Control

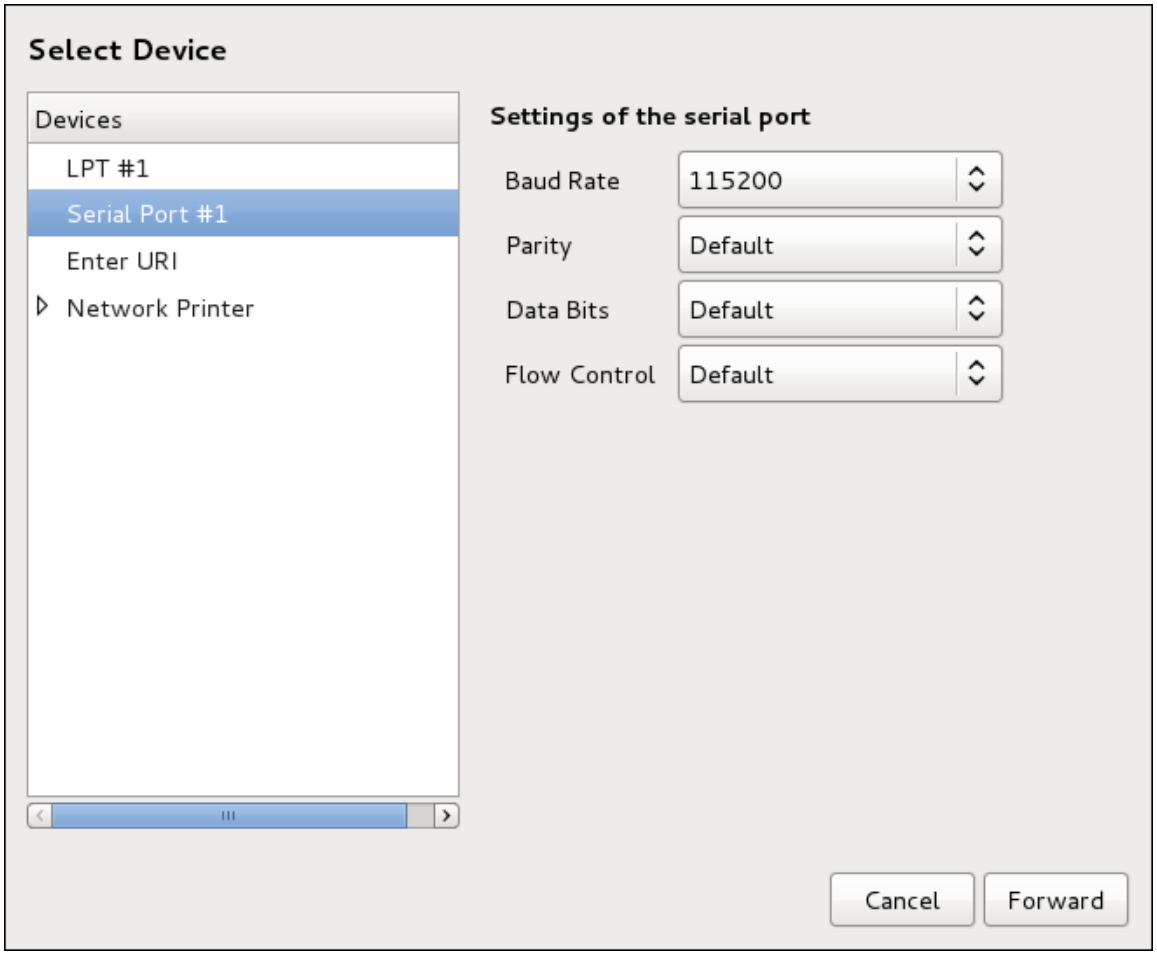


Figure 16.3. Adding a local printer

4. Click **Forward**.

5. Select the printer model. Refer to *Section 16.3.8, "Selecting the Printer Model and Finishing"* for details.

16.3.4. Adding an AppSocket/HP JetDirect printer

Follow this procedure to add an AppSocket/HP JetDirect printer:

1. Open the `New Printer` dialog (refer to *Section 16.3.1, "Starting the Printer Configuration Tool"*).

2. In the list on the left, select **Network Printer** **AppSocket/HP JetDirect**.

3. On the right, enter the connection settings:

   Hostname
   printer hostname or IP address

   Port Number
   printer port listening for print jobs (**`9100`** by default)

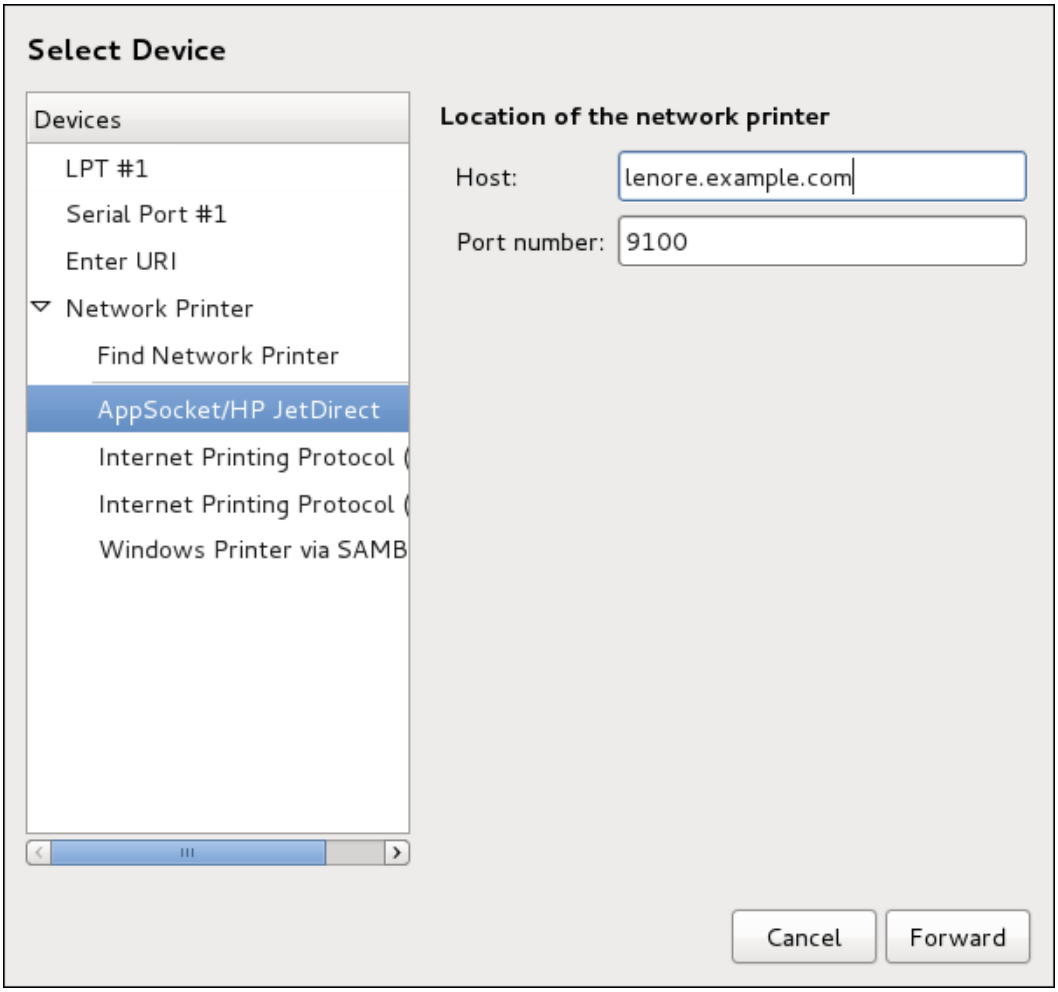


Figure 16.4. Adding a JetDirect printer

4. Click **Forward**.

5. Select the printer model. Refer to *Section 16.3.8, "Selecting the Printer Model and Finishing"* for details.

16.3.5. Adding an IPP Printer

An IPP printer is a printer attached to a different system on the same TCP/IP network. The system this printer is attached to may either be running CUPS or simply configured to use IPP.

If a firewall is enabled on the printer server, then the firewall must be configured to allow incoming TCP connections on port 631. Note that the CUPS browsing protocol allows client machines to discover shared CUPS queues automatically. To enable this, the firewall on the client machine must be configured to allow incoming UDP packets on port 631.

Follow this procedure to add an IPP printer:

1. Open the `New Printer` dialog (refer to *Section 16.3.2, "Starting Printer Setup"*).

2. In the list of devices on the left, select **Network Printer** and **Internet Printing Protocol (ipp)** or **Internet Printing Protocol (https)**.

3. On the right, enter the connection settings:

   Host
   the hostname for the system that controls the printer

   Queue
   the queue name to be given to the new queue (if the box is left empty, a name based on the device node will be used)

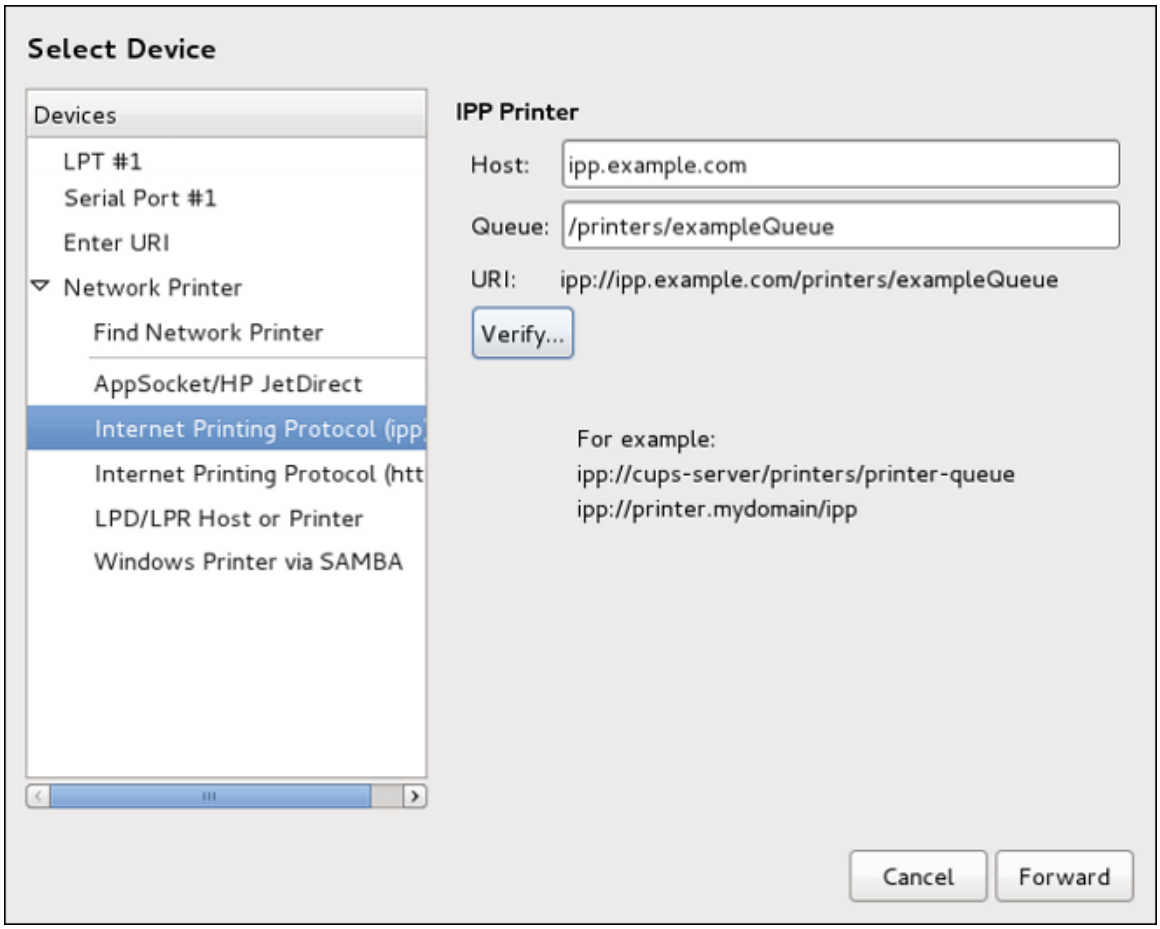


Figure 16.5. Adding an IPP printer

4. Optionally, click **Verify** to detect the printer.

5. Click **Forward** to continue.

6. Select the printer model. Refer to *Section 16.3.8, "Selecting the Printer Model and Finishing"* for details.

16.3.6. Adding an LPD/LPR Host or Printer

Follow this procedure to add an LPD/LPR host or printer:

1. Open the `New Printer` dialog (refer to *Section 16.3.2, "Starting Printer Setup"*).

2. In the list of devices on the left, select **Network Printer□□□ LPD/LPR Host or Printer**.

3. On the right, enter the connection settings:

   Host
   the hostname of the LPD/LPR printer or host

   Optionally, click **Probe** to find queues on the LPD host.

   Queue
   the queue name to be given to the new queue (if the box is left empty, a name based on the device node will be used)

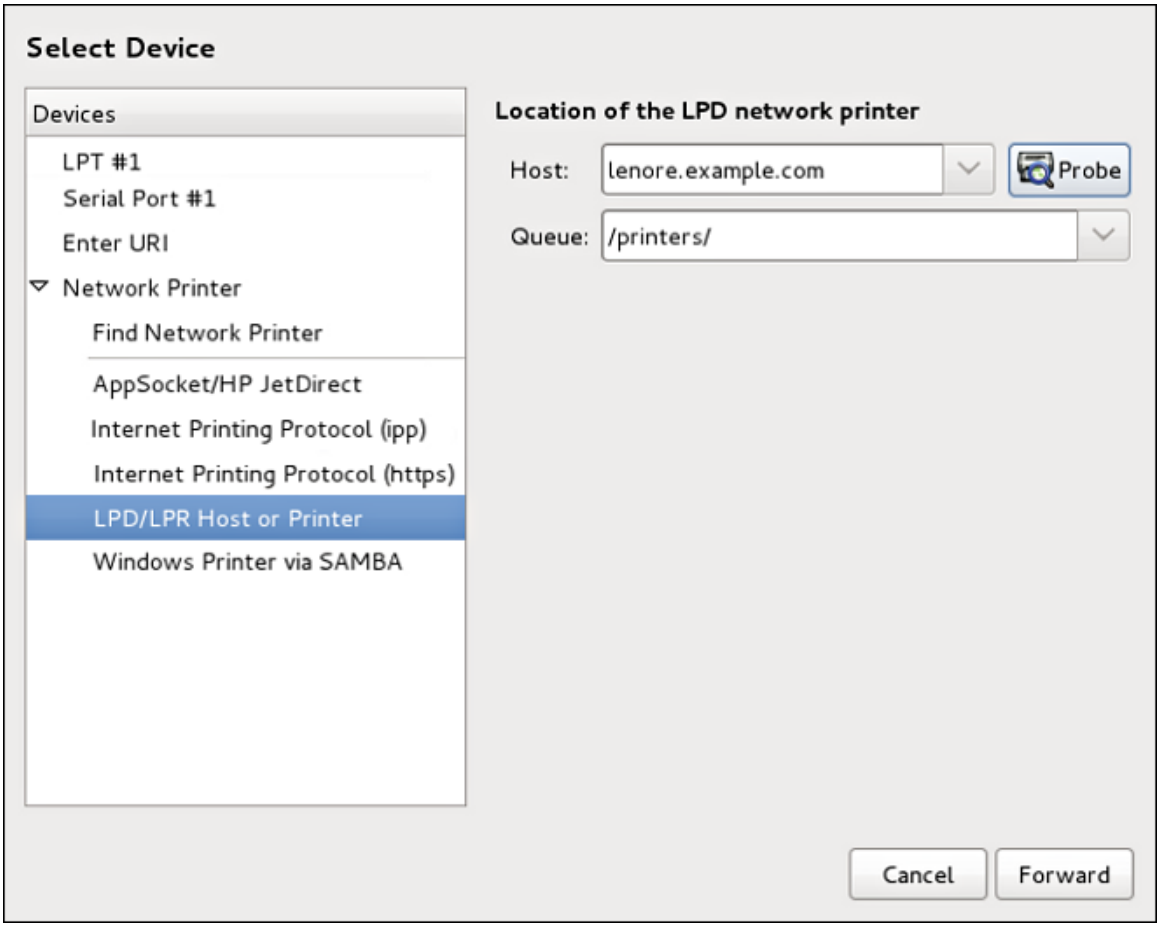


Figure 16.6. Adding an LPD/LPR printer

4. Click **Forward** to continue.

5. Select the printer model. Refer to *Section 16.3.8, "Selecting the Printer Model and Finishing"* for details.

16.3.7. Adding a Samba (SMB) printer

Follow this procedure to add a Samba printer:

Installing the samba-client package

Note that in order to add a Samba printer, you need to have the *samba-client* package installed. You can do so by running, as `root`:

```
yum install samba-client
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

1. Open the `New Printer` dialog (refer to *Section 16.3.2, "Starting Printer Setup"*).
2. In the list on the left, select **Network Printer** **Windows Printer via SAMBA**.
3. Enter the SMB address in the **smb://** field. Use the format *`computer name/printer share`*. In *Figure 16.7, "Adding a SMB printer"*, the *`computer name`* is **`dellbox`** and the *`printer share`* is **`r2`**.

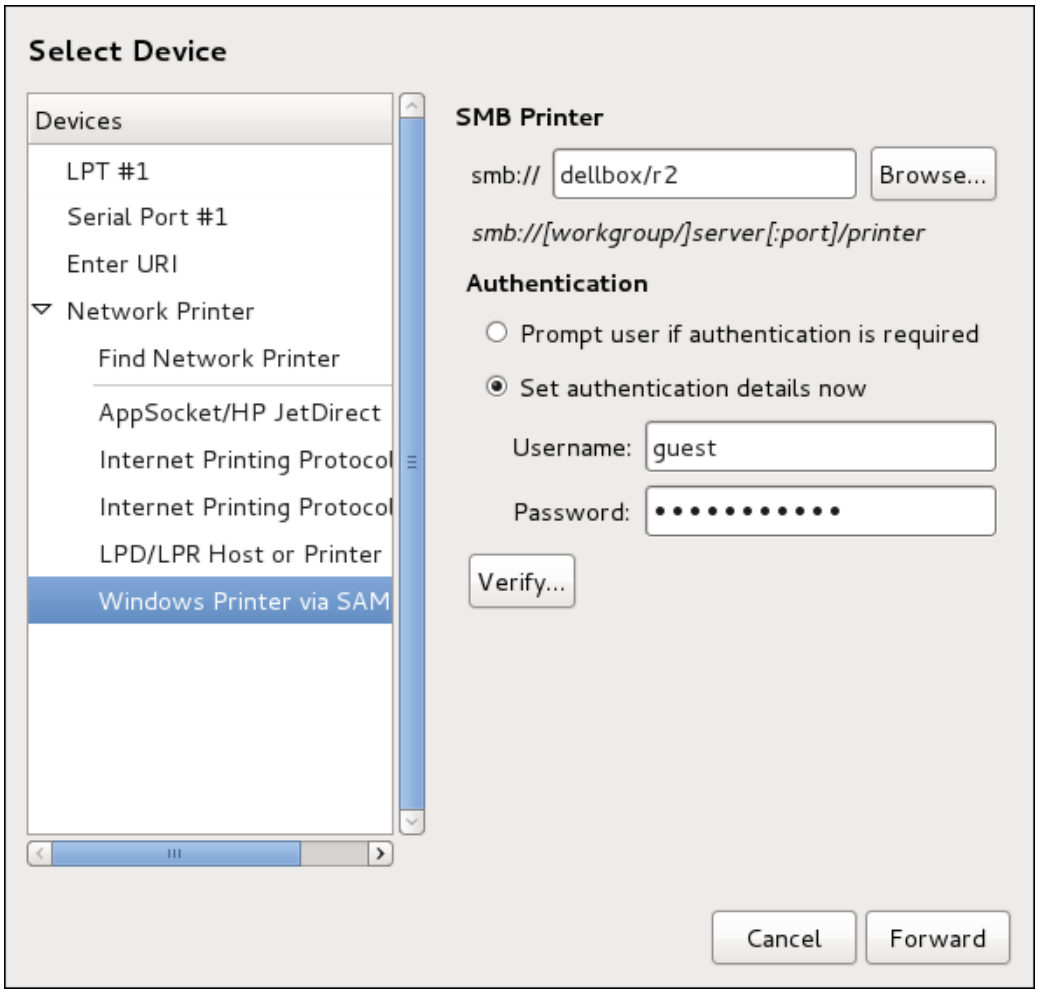


Figure 16.7. Adding a SMB printer

4. Click **Browse** to see the available workgroups/domains. To display only queues of a particular host, type in the host name (NetBios name) and click **Browse**.

5. Select either of the options:

   Prompt user if authentication is required: username and password are collected from the user when printing a document.

   Set authentication details now: provide authentication information now so it is not required later. In the **Username** field, enter the username to access the printer. This user must exist on the SMB system, and the user must have permission to access the printer. The default user name is typically **`guest`** for Windows servers, or **nobody** for Samba servers.

6. Enter the **Password** (if required) for the user specified in the **Username** field.



Be careful when choosing a password

Samba printer usernames and passwords are stored in the printer server as unencrypted files readable by root and lpd. Thus, other users that have root access to the printer server can view the username and password you use to access the Samba printer.

As such, when you choose a username and password to access a Samba printer, it is advisable that you choose a password that is different from what you use to access your local Fedora system.

If there are files shared on the Samba print server, it is recommended that they also use a password different from what is used by the print queue.

7. Click **Verify** to test the connection. Upon successful verification, a dialog box appears confirming printer share accessibility.

8. Click **Forward**.

9. Select the printer model. Refer to *Section 16.3.8, "Selecting the Printer Model and Finishing"* for details.

16.3.8. Selecting the Printer Model and Finishing

Once you have properly selected a printer connection type, the system attempts to acquire a driver. If the process fails, you can locate or search for the driver resources manually.

Follow this procedure to provide the printer driver and finish the installation:

1. In the window displayed after the automatic driver detection has failed, select one of the following options:

   Select printer from database — the system chooses a driver based on the selected make of your printer from the list of **Makes**. If your printer model is not listed, choose **Generic**.

   Provide PPD file — the system uses the provided PostScript Printer Description (PPD) file for installation. A PPD file may also be delivered with your printer as being normally provided by the manufacturer. If the PPD file is available, you can choose this option and use the browser bar below the option description to select the PPD file.

   Search for a printer driver to download — enter the make and model of your printer into the **Make and model** field to search on OpenPrinting.org for the appropriate packages.

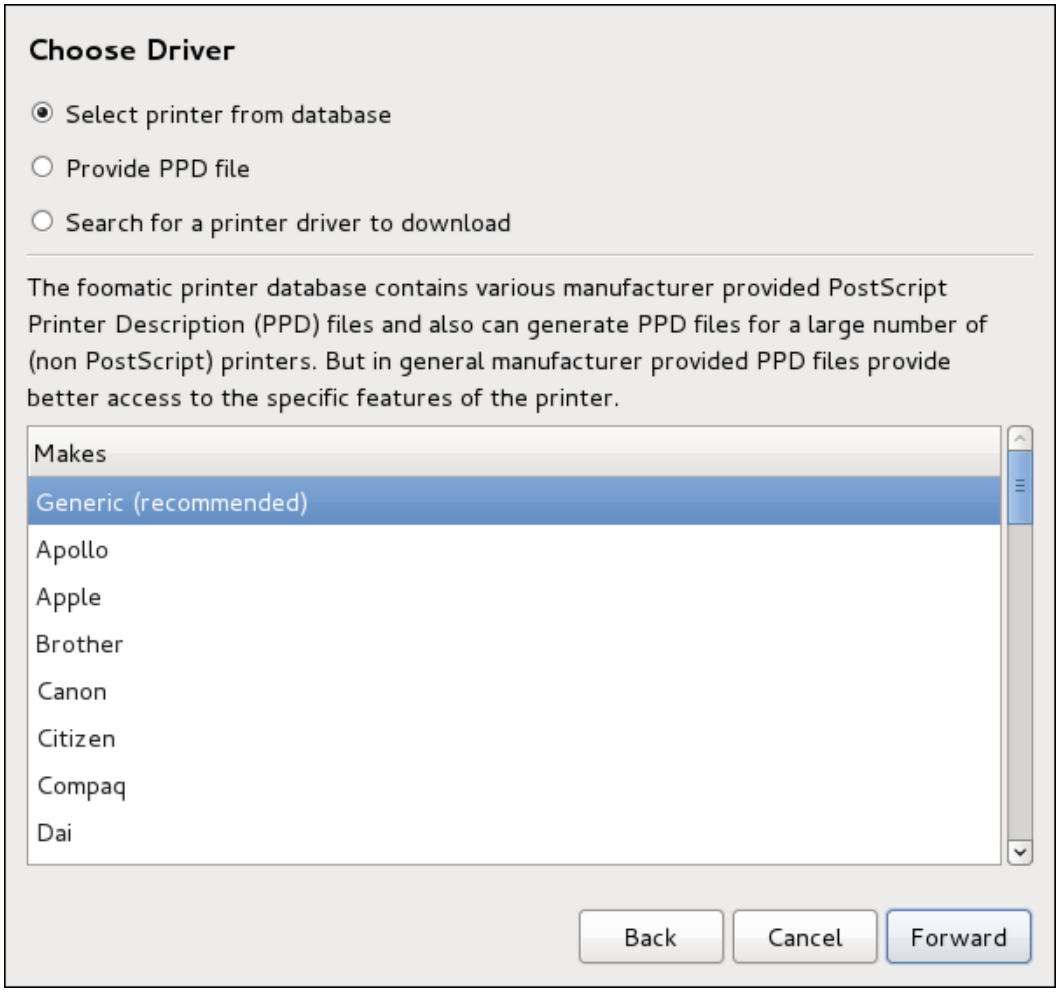


Figure 16.8. Selecting a printer brand

2. Depending on your previous choice provide details in the area displayed below:
   - Printer brand for the **Select printer from database** option
   - PPD file location for the **Provide PPD file** option
   - Printer make and model for the **Search for a printer driver to download** option
3. Click **Forward** to continue.
4. If applicable for your option, window shown in *Figure 16.9, "Selecting a printer model"* appears. Choose the corresponding model in the **Models** column on the left.



Selecting a printer driver

On the right, the recommended printed driver is automatically selected; however, you can select another available driver. The print driver processes the data that you want to print into a format the printer can understand. Since a local printer is attached directly to your computer, you need a printer driver to process the data that is sent to the printer.

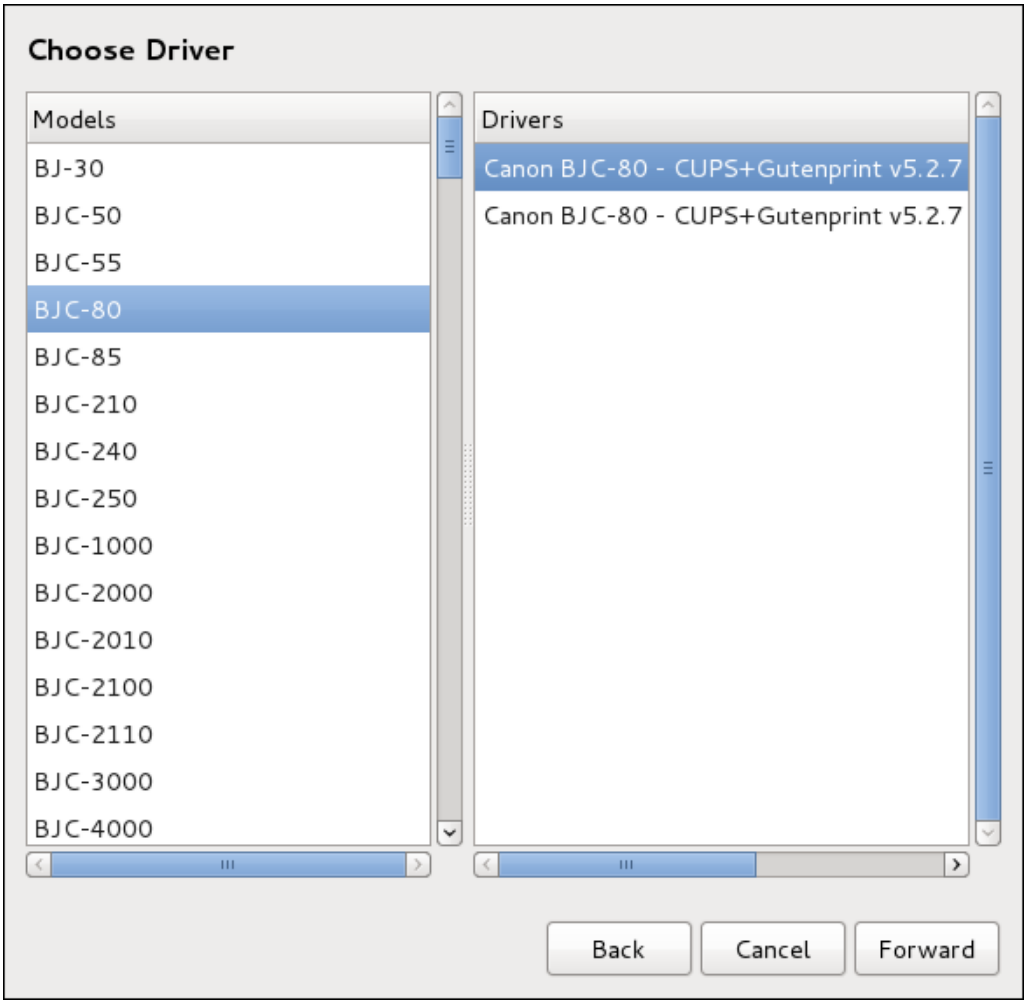


Figure 16.9. Selecting a printer model

5. Click **Forward**.

6. Under the `Describe Printer` enter a unique name for the printer in the **Printer Name** field. The printer name can contain letters, numbers, dashes (-), and underscores (_); it *must not*

contain any spaces. You can also use the **Description** and **Location** fields to add further printer information. Both fields are optional, and may contain spaces.

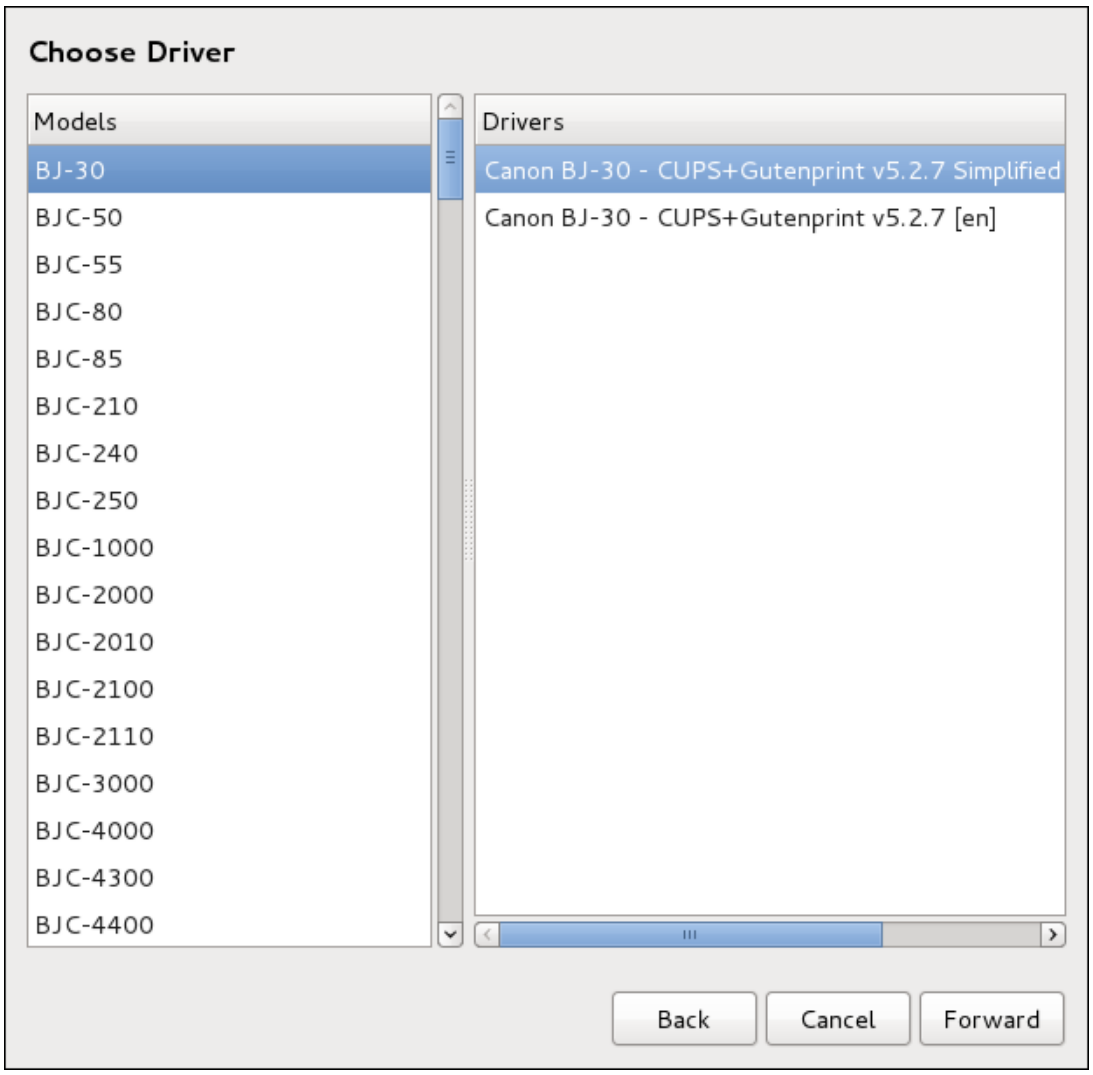


Figure 16.10. Printer setup

7. Click **Apply** to confirm your printer configuration and add the print queue if the settings are correct. Click **Back** to modify the printer configuration.

8. After the changes are applied, a dialog box appears allowing you to print a test page. Click **Print Test Page** to print a test page now. Alternatively, you can print a test page also later, refer to *Section 16.3.9, "Printing a test page"* for details.

16.3.9. Printing a test page

After you have set up a printer or changed a printer configuration, print a test page to make sure the printer is functioning properly:

1. Right-click the printer in the **Printing** window and click **Properties**.

2. In the Properties window, click **Settings** on the left.

3. On the displayed **Settings** tab, click the **Print Test Page** button.

16.3.10. Modifying Existing Printers

To delete an existing printer, in the **Printer Configuration** window, select the printer and go to **Printer** □□ **Delete**. Confirm the printer deletion. Alternatively, press the **Delete** key.

To set the default printer, right-click the printer in the printer list and click the **Set As Default** button in the context menu.

16.3.10.1. The Settings Page

To change printer driver configuration, double-click the corresponding name in the **Printer** list and click the **Settings** label on the left to display the **Settings** page.

You can modify printer settings such as make and model, print a test page, change the device location (URI), and more.

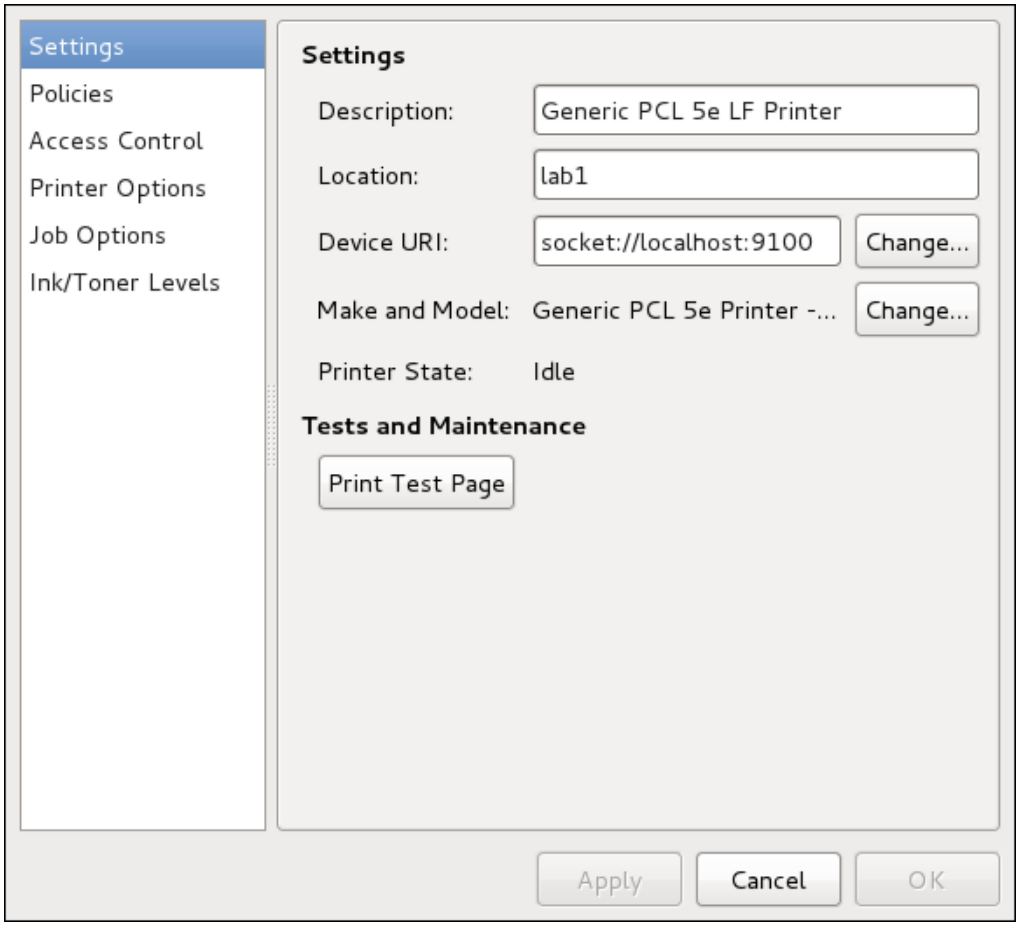


Figure 16.11. Settings page

16.3.10.2. The Policies Page

Click the **Policies** button on the left to change settings in printer state and print output.

You can select the printer states, configure the **Error Policy** of the printer (you can decide to abort the print job, retry, or stop it if an error occurs).

You can also create a *banner page* (a page that describes aspects of the print job such as the originating printer, the username from the which the job originated, and the security status of the

document being printed): click the **Starting Banner** or **Ending Banner** drop-menu and choose the option that best describes the nature of the print jobs (such as **topsecret**, **classified**, or **confidential**).

16.3.10.2.1. Sharing Printers

On the **Policies** page, you can mark a printer as shared: if a printer is shared, users published on the network can use it. To allow the sharing function for printers, go to **Server□□□ Settings** and select **Publish shared printers connected to this system**.

Finally, ensure that the firewall allows incoming TCP connections to port 631, which is Network Printing Server (IPP) in system-config-firewall.

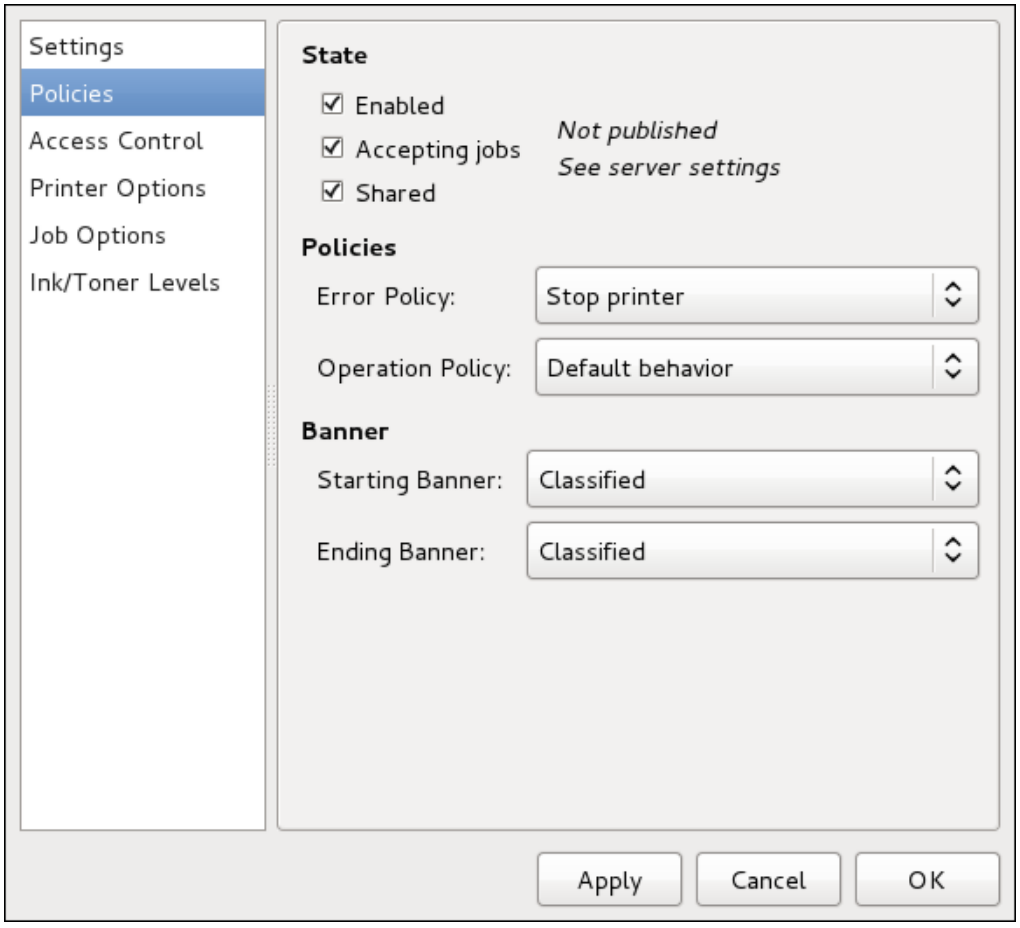


Figure 16.12. Policies page

16.3.10.2.2. The Access Control Page

You can change user-level access to the configured printer on the **Access Control** page. Click the **Access Control** label on the left to display the page. Select either **Allow printing for everyone except these users** or **Deny printing for everyone except these users** and define the user set below: enter the user name in the text box and click the **Add** button to add the user to the user set.

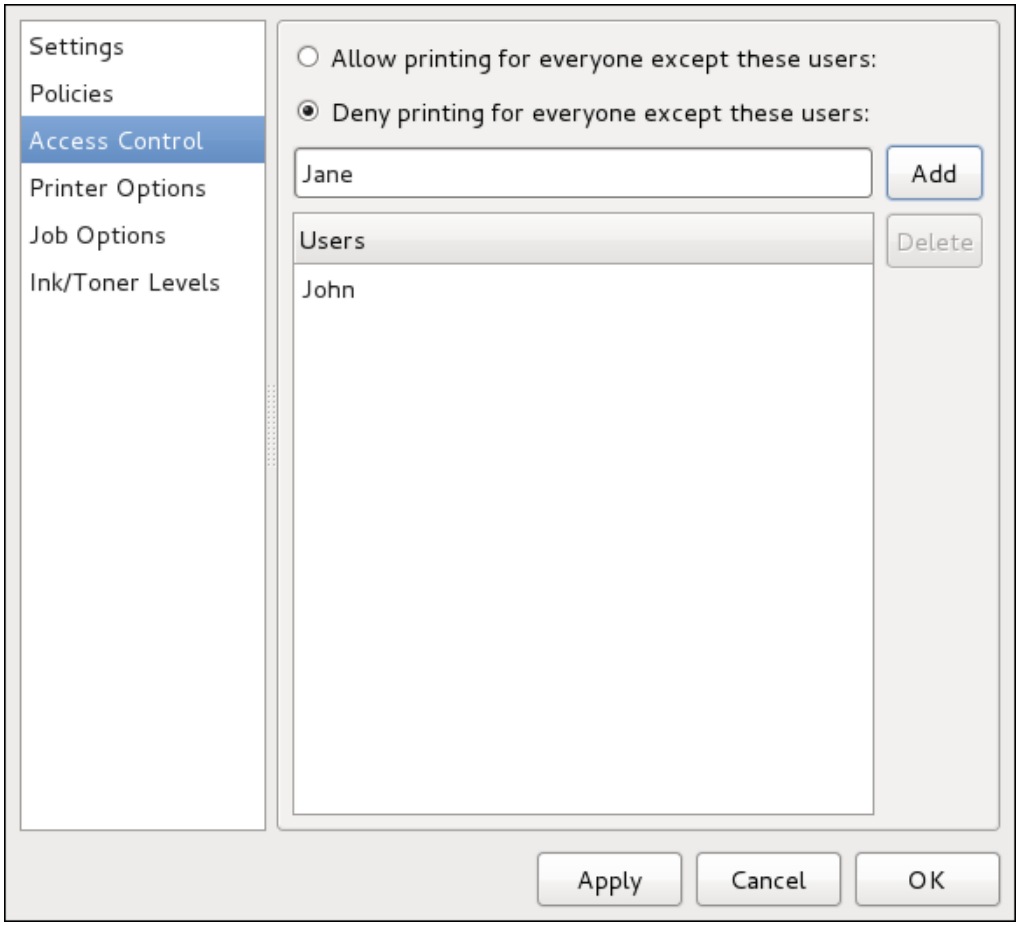


Figure 16.13. Access Control page

16.3.10.2.3. The Printer Options Page

The **Printer Options** page contains various configuration options for the printer media and output, and its content may vary from printer to printer. It contains general printing, paper, quality, and printing size settings.

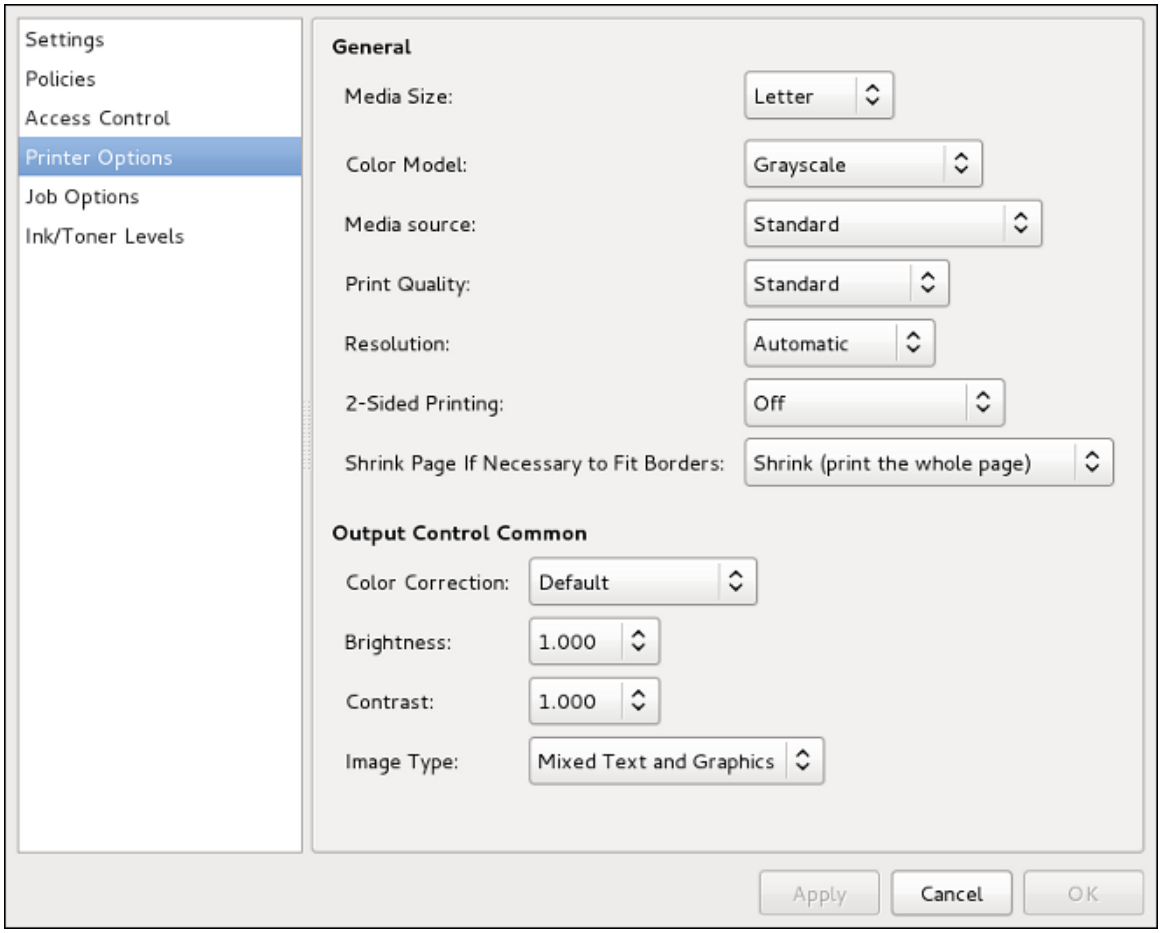


Figure 16.14. Printer Options page

16.3.10.2.4. Job Options Page

On the **Job Options** page, you can detail the printer job options. Click the **Job Options** label on the left to display the page. Edit the default settings to apply custom job options, such as number of copies, orientation, pages per side,scaling (increase or decrease the size of the printable area, which can be used to fit an oversize print area onto a smaller physical sheet of print medium), detailed text options, and custom job options.

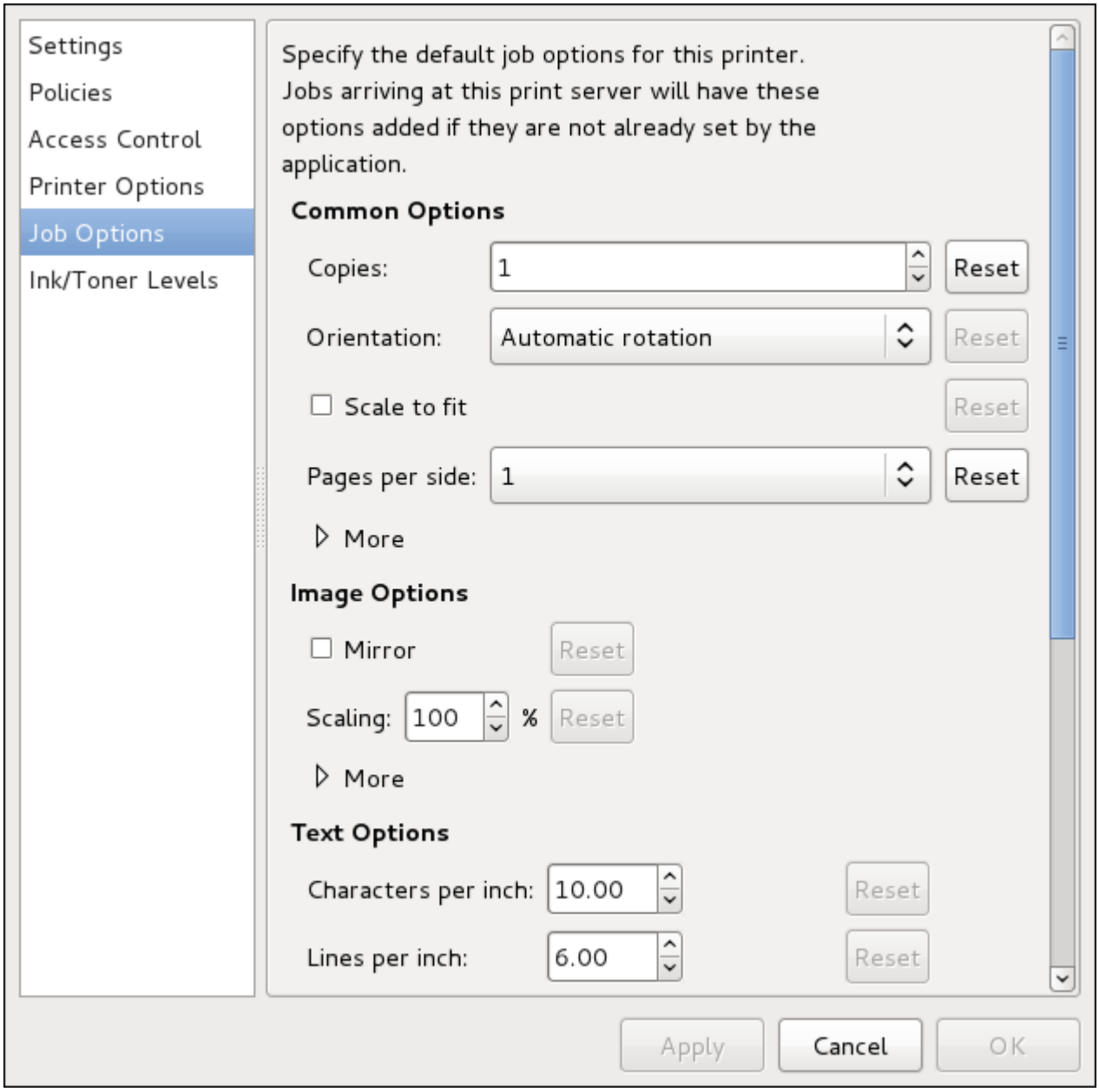


Figure 16.15. Job Options page

16.3.10.2.5. Ink/Toner Levels Page

The **Ink/Toner Levels** page contains details on toner status if available and printer status messages. Click the **Ink/Toner Levels** label on the left to display the page.

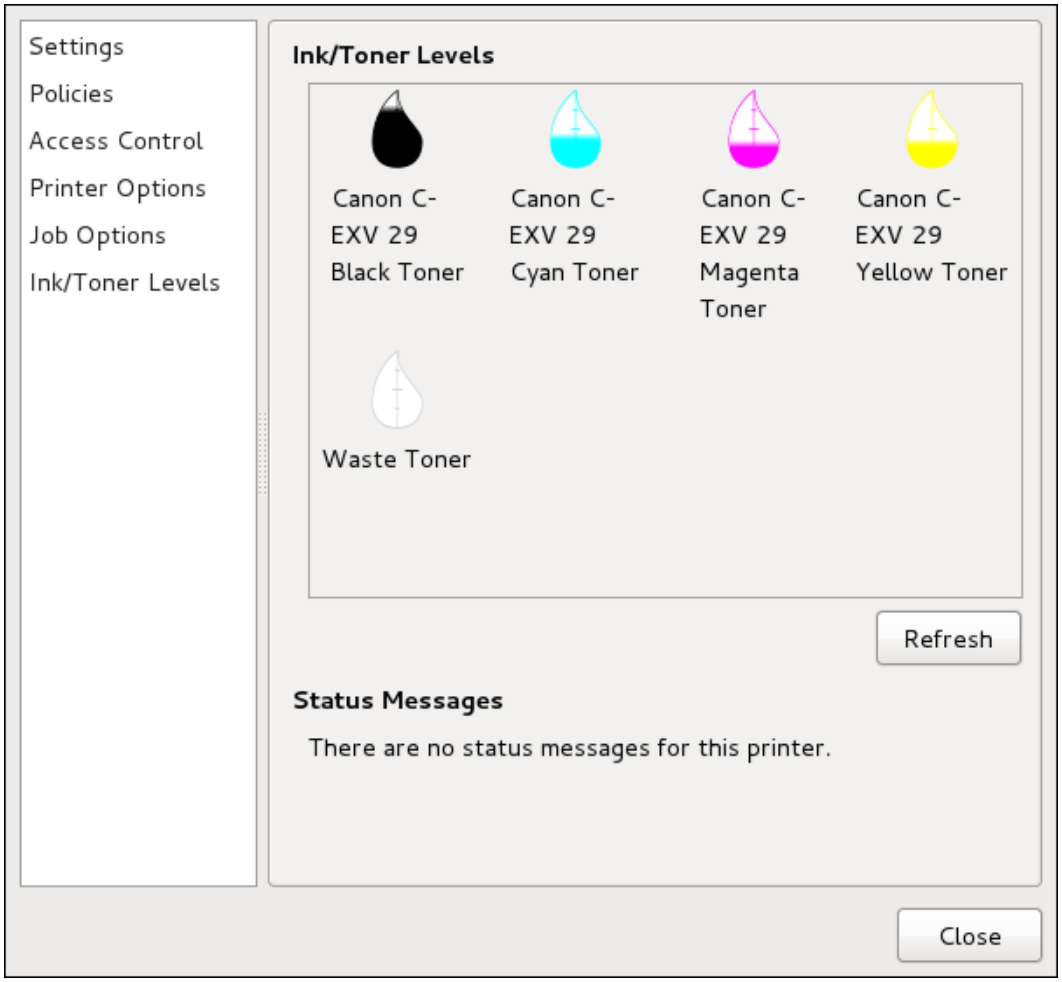


Figure 16.16. Ink/Toner Levels page

16.3.10.3. Managing Print Jobs

When you send a print job to the printer daemon, such as printing a text file from **Emacs** or printing an image from **GIMP**, the print job is added to the print spool queue. The print spool queue is a list of print jobs that have been sent to the printer and information about each print request, such as the status of the request, the job number, and more.

During the printing process, messages informing about the process appear in the notification area.

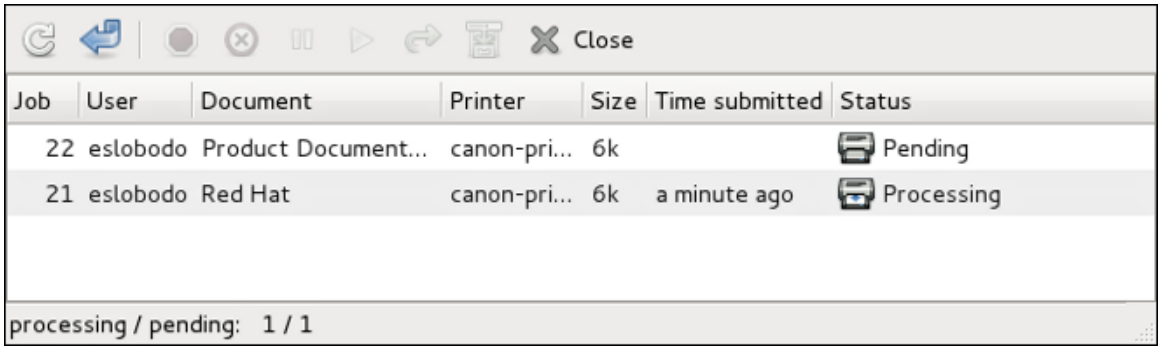


Figure 16.17. GNOME Print Status

To cancel, hold, release, reprint or authenticate a print job, select the job in the **GNOME Print Status** and on the **Job** menu, click the respective command.

To view the list of print jobs in the print spool from a shell prompt, type the command **lpstat -o**. The last few lines look similar to the following:

Example 16.1. Example of **lpstat -o** output

```
$ lpstat -o
Charlie-60              twaugh            1024   Tue 08 Feb 2011 16:42:11 GMT
Aaron-61                twaugh            1024   Tue 08 Feb 2011 16:42:44 GMT
Ben-62                  root              1024   Tue 08 Feb 2011 16:45:42 GMT
```

If you want to cancel a print job, find the job number of the request with the command **lpstat -o** and then use the command **cancel *job number***. For example, **cancel 60** would cancel the print job in *Example 16.1, "Example of **lpstat -o** output"*. You cannot cancel print jobs that were started by other users with the **cancel** command. However, you can enforce deletion of such job by issuing the **cancel -U root *job_number*** command. To prevent such canceling, change the printer operation policy to **Authenticated** to force root authentication.

You can also print a file directly from a shell prompt. For example, the command **lp sample.txt** prints the text file **sample.txt**. The print filter determines what type of file it is and converts it into a format the printer can understand.

16.3.11. Additional Resources

To learn more about printing on Fedora, refer to the following resources.

16.3.11.1. Installed Documentation

man lp
: The manual page for the **lpr** command that allows you to print files from the command line.

man cancel
: The manual page for the command line utility to remove print jobs from the print queue.

man mpage
: The manual page for the command line utility to print multiple pages on one sheet of paper.

man cupsd
: The manual page for the CUPS printer daemon.

man cupsd.conf
: The manual page for the CUPS printer daemon configuration file.

man classes.conf
: The manual page for the class configuration file for CUPS.

man lpstat
: The manual page for the **lpstat** command, which displays status information about classes, jobs, and printers.

16.3.11.2. Useful Websites

http://www.linuxprinting.org/
: *GNU/Linux Printing* contains a large amount of information about printing in Linux.

http://www.cups.org/
: Documentation, FAQs, and newsgroups about CUPS.

Part VI. Monitoring and Automation

This part describes various tools that allow system administrators to monitor system performance, automate system tasks, and report bugs.

System Monitoring Tools

In order to configure the system, system administrators often need to determine the amount of free memory, how much free disk space is available, how the hard drive is partitioned, or what processes are running.

17.1. Viewing System Processes

17.1.1. Using the ps Command

The **ps** command allows you to display information about running processes. It produces a static list, that is, a snapshot of what is running when you execute the command. If you want a constantly updated list of running processes, use the **top** command or the **System Monitor** application instead.

To list all processes that are currently running on the system including processes owned by other users, type the following at a shell prompt:

```
ps ax
```

For each listed process, the **ps ax** command displays the process ID (**PID**), the terminal that is associated with it (**TTY**), the current status (**STAT**), the cumulated CPU time (**TIME**), and the name of the executable file (**COMMAND**). For example:

```
~]$ ps ax
  PID TTY      STAT   TIME COMMAND
    1 ?        Ss     0:02 /usr/lib/systemd/systemd --system --deserialize 20
    2 ?        S      0:00 [kthreadd]
    3 ?        S      0:00 [ksoftirqd/0]
    5 ?        S      0:00 [kworker/u:0]
    6 ?        S      0:00 [migration/0]
[output truncated]
```

To display the owner alongside each process, use the following command:

```
ps aux
```

Apart from the information provided by the **ps ax** command, **ps aux** displays the effective username of the process owner (**USER**), the percentage of the CPU (**%CPU**) and memory (**%MEM**) usage, the virtual memory size in kilobytes (**VSZ**), the non-swapped physical memory size in kilobytes (**RSS**), and the time or date the process was started. For instance:

```
~]$ ps aux
USER       PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root         1  0.0  0.3  53128  2988 ?        Ss   13:28   0:02 /usr/lib/systemd/systemd --
system --deserialize 20
root         2  0.0  0.0      0     0 ?        S    13:28   0:00 [kthreadd]
root         3  0.0  0.0      0     0 ?        S    13:28   0:00 [ksoftirqd/0]
root         5  0.0  0.0      0     0 ?        S    13:28   0:00 [kworker/u:0]
root         6  0.0  0.0      0     0 ?        S    13:28   0:00 [migration/0]
[output truncated]
```

You can also use the **ps** command in a combination with **grep** to see if a particular process is running. For example, to determine if **Emacs** is running, type:

```
~]$ ps ax | grep emacs
 2625 ?        Sl     0:00 emacs
```

For a complete list of available command line options, refer to the **ps**(1) manual page.

17.1.2. Using the top Command

The **top** command displays a real-time list of processes that are running on the system. It also displays additional information about the system uptime, current CPU and memory usage, or total number of running processes, and allows you to perform actions such as sorting the list or killing a process.

To run the **top** command, type the following at a shell prompt:

```
top
```

For each listed process, the **top** command displays the process ID (**PID**), the effective username of the process owner (**USER**), the priority (**PR**), the nice value (**NI**), the amount of virtual memory the process uses (**VIRT**), the amount of non-swapped physical memory the process uses (**RES**), the amount of shared memory the process uses (**SHR**), the percentage of the CPU (**%CPU**) and memory (**%MEM**) usage, the cumulated CPU time (**TIME+**), and the name of the executable file (**COMMAND**). For example:

```
~]$ top
top - 19:22:08 up  5:53,  3 users,  load average: 1.08, 1.03, 0.82
Tasks: 117 total,   2 running, 115 sleeping,   0 stopped,   0 zombie
Cpu(s):  9.3%us,  1.3%sy,  0.0%ni, 85.1%id,  0.0%wa,  1.7%hi,  0.0%si,  2.6%st
Mem:    761956k total,   617256k used,   144700k free,    24356k buffers
Swap:  1540092k total,    55780k used,  1484312k free,   256408k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
  510 john      20   0 1435m  99m  18m S  9.0 13.3   3:30.52 gnome-shell
32686 root      20   0  156m  27m 3628 R  2.0  3.7   0:48.69 Xorg
 2625 john      20   0  488m  27m  14m S  0.3  3.7   0:00.70 emacs
    1 root      20   0 53128 2640 1152 S  0.0  0.3   0:02.83 systemd
    2 root      20   0     0    0    0 S  0.0  0.0   0:00.01 kthreadd
    3 root      20   0     0    0    0 S  0.0  0.0   0:00.18 ksoftirqd/0
    5 root      20   0     0    0    0 S  0.0  0.0   0:00.00 kworker/u:0
    6 root      RT   0     0    0    0 S  0.0  0.0   0:00.00 migration/0
    7 root      RT   0     0    0    0 S  0.0  0.0   0:00.30 watchdog/0
    8 root       0 -20     0    0    0 S  0.0  0.0   0:00.00 cpuset
    9 root       0 -20     0    0    0 S  0.0  0.0   0:00.00 khelper
   10 root      20   0     0    0    0 S  0.0  0.0   0:00.00 kdevtmpfs
   11 root       0 -20     0    0    0 S  0.0  0.0   0:00.00 netns
   12 root      20   0     0    0    0 S  0.0  0.0   0:00.11 sync_supers
   13 root      20   0     0    0    0 S  0.0  0.0   0:00.00 bdi-default
   14 root       0 -20     0    0    0 S  0.0  0.0   0:00.00 kintegrityd
   15 root       0 -20     0    0    0 S  0.0  0.0   0:00.00 kblockd
```

Table 17.1, "Interactive top commands" contains useful interactive commands that you can use with **top**. For more information, refer to the **top**(1) manual page.

Table 17.1. Interactive top commands

Command	Description
Enter, **Space**	Immediately refreshes the display.
h, **?**	Displays a help screen.

Command	Description
k	Kills a process. You are prompted for the process ID and the signal to send to it.
n	Changes the number of displayed processes. You are prompted to enter the number.
u	Sorts the list by user.
M	Sorts the list by memory usage.
P	Sorts the list by CPU usage.
q	Terminates the utility and returns to the shell prompt.

17.1.3. Using the System Monitor Tool

The **Processes** tab of the **System Monitor** tool allows you to view, search for, change the priority of, and kill processes from the graphical user interface.

To start the **System Monitor** tool, either select **Applications** **System Tools** **System Monitor** from the **Activities** menu, or type **`gnome-system-monitor`** at a shell prompt. Then click the **Processes** tab to view the list of running processes.

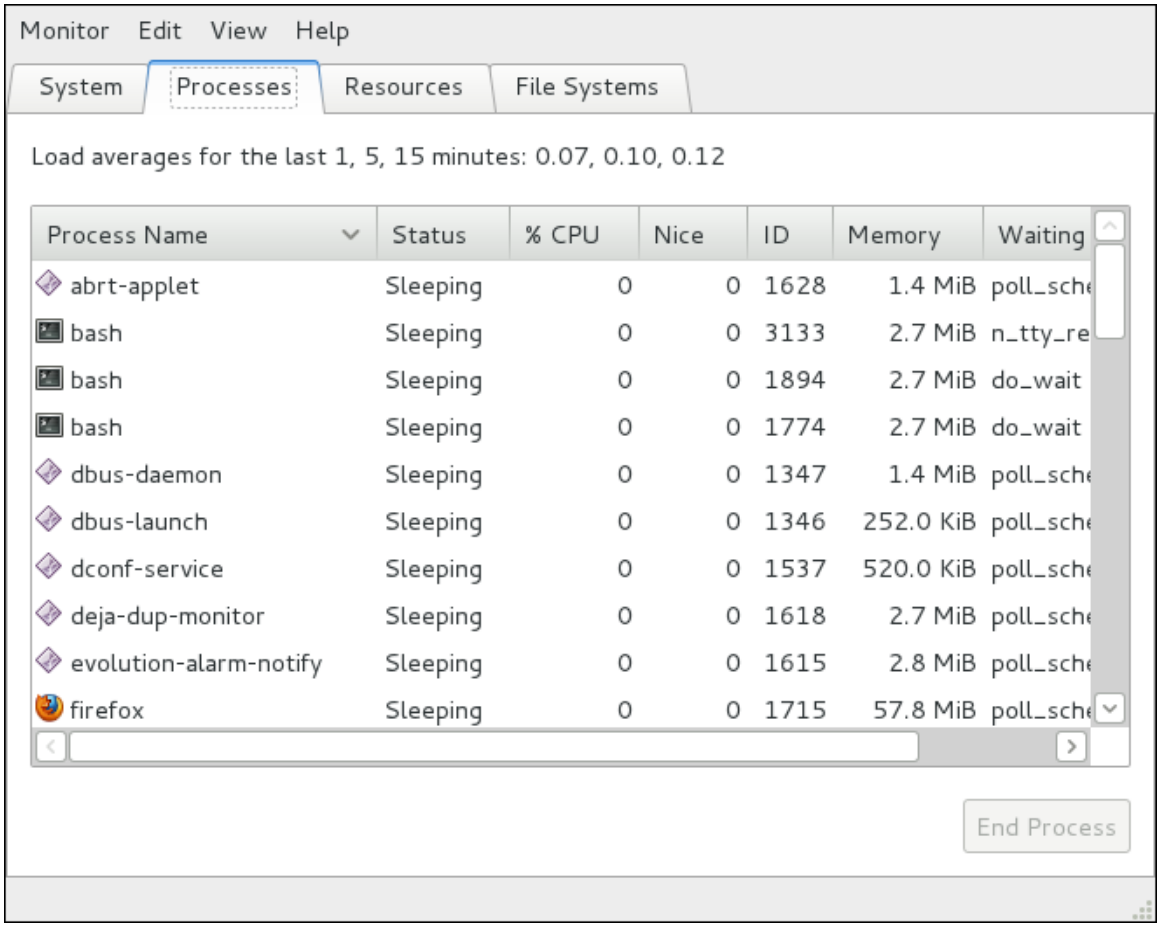


Figure 17.1. System Monitor — Processes

For each listed process, the **System Monitor** tool displays its name (**Process Name**), current status (**Status**), percentage of the memory usage (**% CPU**), nice value (**Nice**), process ID (**ID**), memory usage (**Memory**), the channel the process is waiting in (**Waiting Channel**), and additional details about the session (**Session**). To sort the information by a specific column in ascending order, click the

name of that column. Click the name of the column again to toggle the sort between ascending and descending order.

By default, the **System Monitor** tool displays a list of processes that are owned by the current user. Selecting various options from the **View** menu allows you to:

- view only active processes,
- view all processes,
- view your processes,
- view process dependencies,
- view a memory map of a selected process,
- view the files opened by a selected process, and
- refresh the list of processes.

Additionally, various options in the **Edit** menu allows you to:

- stop a process,
- continue running a stopped process,
- end a process,
- kill a process,
- change the priority of a selected process, and
- edit the **System Monitor** preferences, such as the refresh interval for the list of processes, or what information to show.

You can also end a process by selecting it from the list and clicking the **End Process** button.

17.2. Viewing Memory Usage

17.2.1. Using the free Command

The **free** command allows you to display the amount of free and used memory on the system. To do so, type the following at a shell prompt:

```
free
```

The **free** command provides information about both the physical memory (**Mem**) and swap space (**Swap**). It displays the total amount of memory (**total**), as well as the amount of memory that is in use (**used**), free (**free**), shared (**shared**), in kernel buffers (**buffers**), and cached (**cached**). For example:

```
~]$ free
             total       used       free     shared    buffers     cached
Mem:        761956     607500     154456          0      37404     156176
-/+ buffers/cache:     413920     348036
```

```
Swap:      1540092      84408    1455684
```

By default, **free** displays the values in kilobytes. To display the values in megabytes, supply the **-m** command line option:

```
free -m
```

For instance:

```
~]$ free -m
             total       used       free     shared    buffers     cached
Mem:           744        593        150          0         36        152
-/+ buffers/cache:        404        339
Swap:         1503         82       1421
```

For a complete list of available command line options, refer to the **free**(1) manual page.

17.2.2. Using the System Monitor Tool

The **Resources** tab of the **System Monitor** tool allows you to view the amount of free and used memory on the system.

To start the **System Monitor** tool, either select **Applications** □□□ **System Tools** □□□ **System Monitor** from the **Activities** menu, or type **gnome-system-monitor** at a shell prompt. Then click the **Resources** tab to view the system's memory usage.

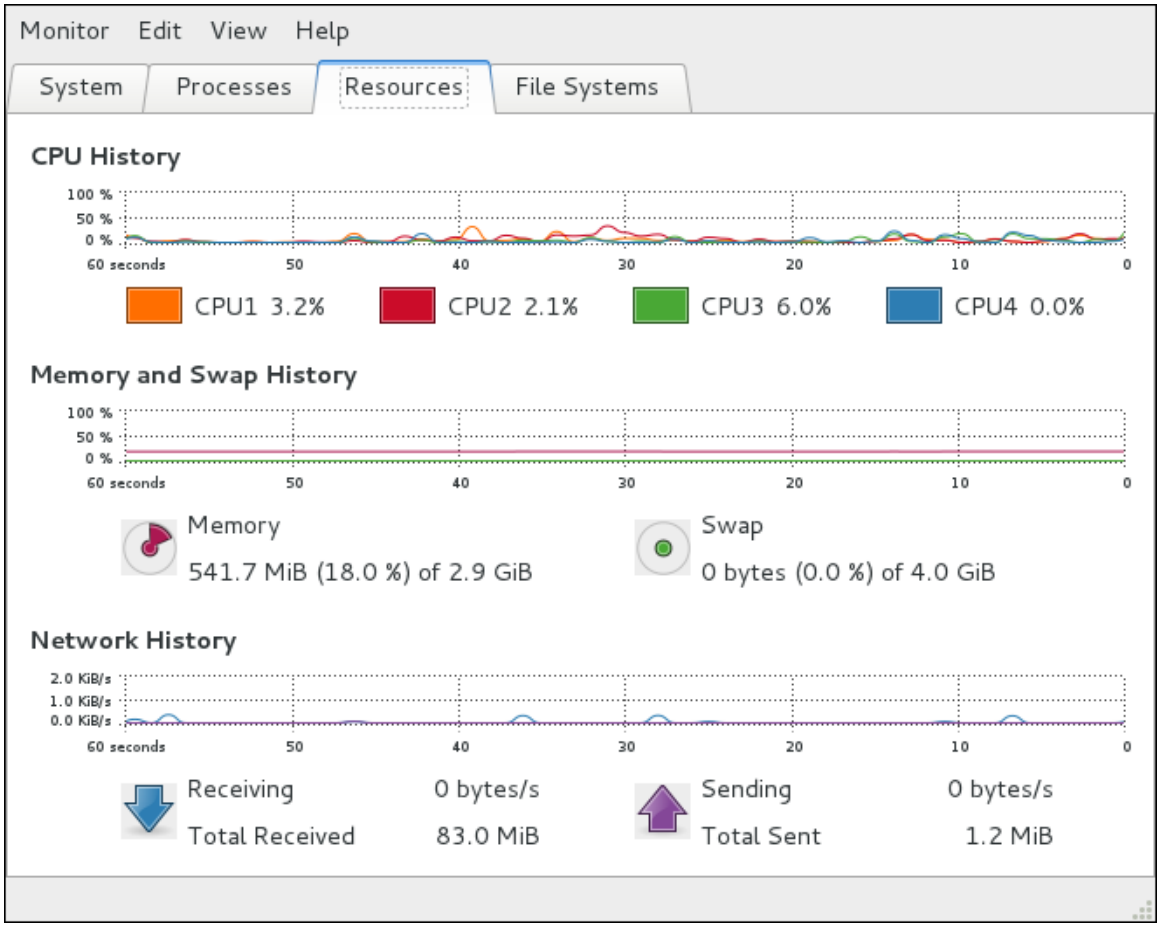


Figure 17.2. System Monitor — Resources

In the **Memory and Swap History** section, the **System Monitor** tool displays a graphical representation of the memory and swap usage history, as well as the total amount of the physical memory (**Memory**) and swap space (**Swap**) and how much of it is in use.

17.3. Viewing CPU Usage

17.3.1. Using the System Monitor Tool

The **Resources** tab of the **System Monitor** tool allows you to view the current CPU usage on the system.

To start the **System Monitor** tool, either select **Applications** **System Tools** **System Monitor** from the **Activities** menu, or type **`gnome-system-monitor`** at a shell prompt. Then click the **Resources** tab to view the system's CPU usage.

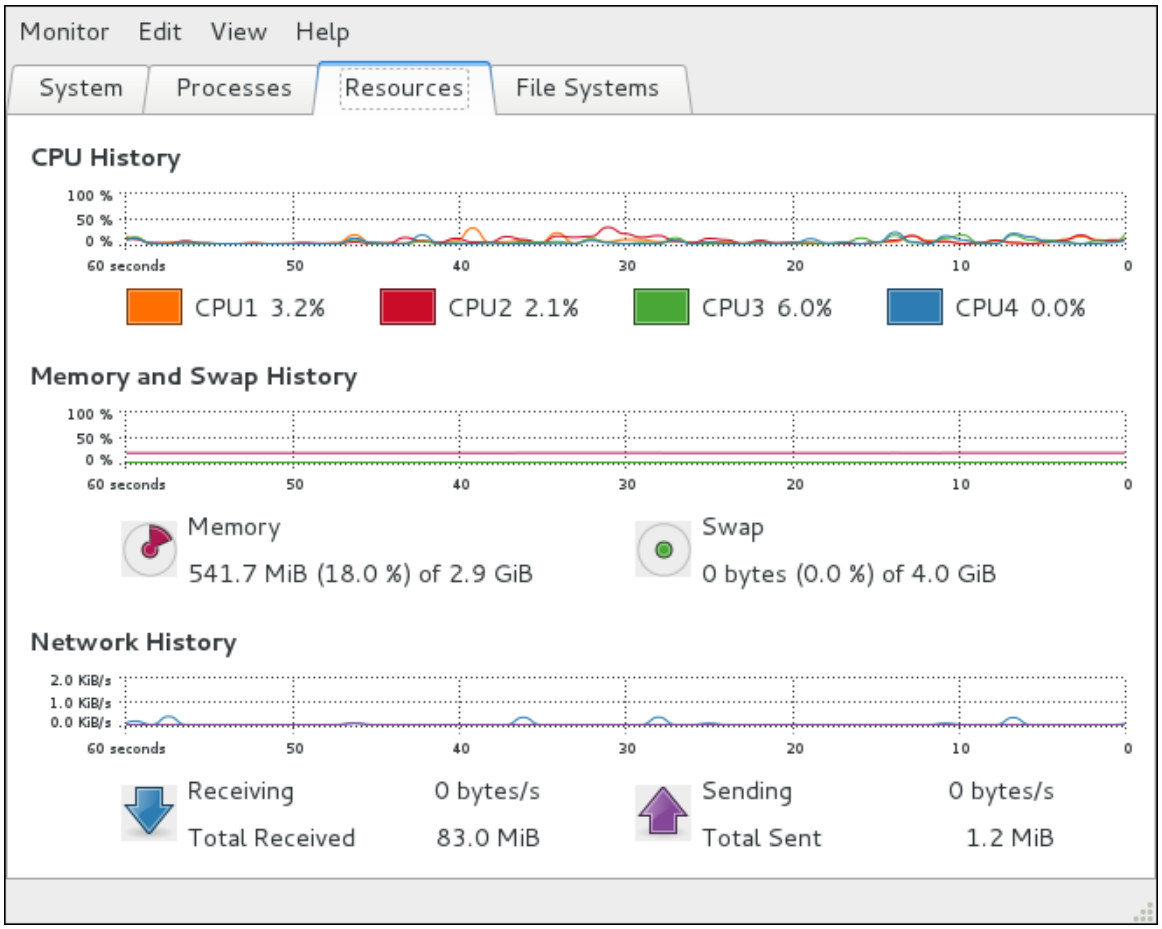


Figure 17.3. System Monitor — Resources

In the **CPU History** section, the **System Monitor** tool displays a graphical representation of the CPU usage history and shows the percentage of how much CPU is currently in use.

17.4. Viewing Block Devices and File Systems

17.4.1. Using the lsblk Command

The **lsblk** command allows you to display a list of available block devices. To do so, type the following at a shell prompt:

```
lsblk
```

For each listed block device, the **lsblk** command displays the device name (**NAME**), major and minor device number (**MAJ:MIN**), if the device is removable (**RM**), what is its size (**SIZE**), if the device is read-only (**RO**), what type is it (**TYPE**), and where the device is mounted (**MOUNTPOINT**). For example:

```
~]$ lsblk
NAME                          MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sr0                            11:0    1  1024M  0 rom
vda                           252:0    0    20G  0 disk
|-vda1                        252:1    0   500M  0 part /boot
`-vda2                        252:2    0  19.5G  0 part
  |-vg_fedora-lv_swap (dm-0) 253:0    0   1.5G  0 lvm  [SWAP]
  `-vg_fedora-lv_root (dm-1) 253:1    0    18G  0 lvm  /
```

By default, **lsblk** lists block devices in a tree-like format. To display the information as an ordinary list, add the **-l** command line option:

```
lsblk -l
```

For instance:

```
~]$ lsblk -l
NAME                        MAJ:MIN RM   SIZE RO TYPE MOUNTPOINT
sr0                          11:0    1  1024M  0 rom
vda                         252:0    0    20G  0 disk
vda1                        252:1    0   500M  0 part /boot
vda2                        252:2    0  19.5G  0 part
vg_fedora-lv_swap (dm-0) 253:0    0   1.5G  0 lvm  [SWAP]
vg_fedora-lv_root (dm-1) 253:1    0    18G  0 lvm  /
```

For a complete list of available command line options, refer to the **lsblk**(8) manual page.

17.4.2. Using the blkid Command

The **blkid** command allows you to display information about available block devices. To do so, type the following at a shell prompt as `root`:

```
blkid
```

For each listed block device, the **blkid** command displays available attributes such as its *universally unique identifier* (**UUID**), file system type (**TYPE**), or volume label (**LABEL**). For example:

```
~]# blkid
/dev/vda1: UUID="4ea24c68-ab10-47d4-8a6b-b8d3a002acba" TYPE="ext4"
/dev/vda2: UUID="iJ9YwJ-leFf-A1zb-VVaK-H9t1-raLW-HoqlUG" TYPE="LVM2_member"
/dev/mapper/vg_fedora-lv_swap: UUID="d6d755bc-3e3e-4e8f-9bb5-a5e7f4d86ffd" TYPE="swap"
/dev/mapper/vg_fedora-lv_root: LABEL="_Fedora-17-x86_6" UUID="77ba9149-751a-48e0-974f-
ad94911734b9" TYPE="ext4"
```

By default, the **lsblk** command lists all available block devices. To display information about a particular device only, specify the device name on the command line:

```
blkid device_name
```

For instance, to display information about **/dev/vda1**, type:

```
~]# blkid /dev/vda1
/dev/vda1: UUID="4ea24c68-ab10-47d4-8a6b-b8d3a002acba" TYPE="ext4"
```

You can also use the above command with the **-p** and **-o udev** command line options to obtain more detailed information. Note that `root` privileges are required to run this command:

```
blkid -po udev device_name
```

For example:

```
~]# blkid -po udev /dev/vda1
ID_FS_UUID=4ea24c68-ab10-47d4-8a6b-b8d3a002acba
ID_FS_UUID_ENC=4ea24c68-ab10-47d4-8a6b-b8d3a002acba
ID_FS_VERSION=1.0
ID_FS_TYPE=ext4
ID_FS_USAGE=filesystem
ID_PART_ENTRY_SCHEME=dos
ID_PART_ENTRY_TYPE=0x83
ID_PART_ENTRY_FLAGS=0x80
ID_PART_ENTRY_NUMBER=1
ID_PART_ENTRY_OFFSET=2048
ID_PART_ENTRY_SIZE=1024000
ID_PART_ENTRY_DISK=252:0
```

For a complete list of available command line options, refer to the **blkid**(8) manual page.

17.4.3. Using the partx Command

The **partx** command allows you to display a list of disk partitions. To list the partition table of a particular disk, as `root`, run this command with the **-s** option followed by the device name:

```
partx -s device_name
```

For example, to list partitions on **/dev/vda**, type:

```
~]# partx -s /dev/vda
NR   START      END  SECTORS  SIZE NAME UUID
 1    2048  1026047  1024000  500M
 2 1026048 41943039 40916992 19.5G
```

For a complete list of available command line options, refer to the **partx**(8) manual page.

17.4.4. Using the findmnt Command

The **findmnt** command allows you to display a list of currently mounted file systems. To do so, type the following at a shell prompt:

```
findmnt
```

For each listed file system, the **findmnt** command displays the target mount point (**TARGET**), source device (**SOURCE**), file system type (**FSTYPE**), and relevant mount options (**OPTIONS**). For example:

```
~]$ findmnt
TARGET                           SOURCE     FSTYPE   OPTIONS
/                                /dev/mapper/vg_fedora-lv_root
                                            ext4     rw,relatime,seclabel,data=o
|-/proc                          proc       proc     rw,nosuid,nodev,noexec,rela
| `-/proc/sys/fs/binfmt_misc     systemd-1  autofs   rw,relatime,fd=23,pgrp=1,ti
|-/sys                           sysfs      sysfs    rw,nosuid,nodev,noexec,rela
| |-/sys/kernel/security         securityfs security rw,nosuid,nodev,noexec,rela
| |-/sys/fs/selinux              selinuxfs  selinuxf rw,relatime
| |-/sys/fs/cgroup               tmpfs      tmpfs    rw,nosuid,nodev,noexec,secl
| | |-/sys/fs/cgroup/systemd     cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/cpuset      cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/cpu,cpuacct cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/memory      cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/devices     cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/freezer     cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/net_cls     cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | |-/sys/fs/cgroup/blkio       cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| | `-/sys/fs/cgroup/perf_event  cgroup     cgroup   rw,nosuid,nodev,noexec,rela
| |-/sys/kernel/debug            debugfs    debugfs  rw,relatime
| `-/sys/kernel/config           configfs   configfs rw,relatime
[output truncated]
```

By default, **findmnt** lists file systems in a tree-like format. To display the information as an ordinary list, add the **-l** command line option:

```
findmnt -l
```

For instance:

```
~]$ findmnt -l
TARGET                    SOURCE     FSTYPE   OPTIONS
/proc                     proc       proc     rw,nosuid,nodev,noexec,relatime
/sys                      sysfs      sysfs    rw,nosuid,nodev,noexec,relatime,s
/dev                      devtmpfs   devtmpfs rw,nosuid,seclabel,size=370080k,n
/dev/pts                  devpts     devpts   rw,nosuid,noexec,relatime,seclabe
/dev/shm                  tmpfs      tmpfs    rw,nosuid,nodev,seclabel
/run                      tmpfs      tmpfs    rw,nosuid,nodev,seclabel,mode=755
/                         /dev/mapper/vg_fedora-lv_root
                                     ext4     rw,relatime,seclabel,data=ordered
/sys/kernel/security      securityfs security rw,nosuid,nodev,noexec,relatime
/sys/fs/selinux           selinuxfs  selinuxf rw,relatime
/sys/fs/cgroup            tmpfs      tmpfs    rw,nosuid,nodev,noexec,seclabel,m
/sys/fs/cgroup/systemd    cgroup     cgroup   rw,nosuid,nodev,noexec,relatime,r
[output truncated]
```

You can also choose to list only file systems of a particular type. To do so, add the **-t** command line option followed by a file system type:

```
findmnt -t type
```

For example, to all list `ext4` file systems, type:

```
~]$ findmnt -t ext4
TARGET SOURCE                      FSTYPE OPTIONS
```

```
/      /dev/mapper/vg_fedora-lv_root ext4   rw,relatime,seclabel,data=ordered
/boot  /dev/vda1                     ext4   rw,relatime,seclabel,data=ordered
```

For a complete list of available command line options, refer to the **findmnt**(8) manual page.

17.4.5. Using the df Command

The **df** command allows you to display a detailed report on the system's disk space usage. To do so, type the following at a shell prompt:

```
df
```

For each listed file system, the **df** command displays its name (**Filesystem**), size (**1K-blocks** or **Size**), how much space is used (**Used**), how much space is still available (**Available**), the percentage of space usage (**Use%**), and where is the file system mounted (**Mounted on**). For example:

```
~]$ df
Filesystem                     1K-blocks    Used Available Use% Mounted on
rootfs                          18877356 4605476  14082844  25% /
devtmpfs                          370080       0    370080   0% /dev
tmpfs                             380976     256    380720   1% /dev/shm
tmpfs                             380976    3048    377928   1% /run
/dev/mapper/vg_fedora-lv_root   18877356 4605476  14082844  25% /
tmpfs                             380976       0    380976   0% /sys/fs/cgroup
tmpfs                             380976       0    380976   0% /media
/dev/vda1                         508745   85018    398127  18% /boot
```

By default, the **df** command shows the partition size in 1 kilobyte blocks and the amount of used and available disk space in kilobytes. To view the information in megabytes and gigabytes, supply the **-h** command line option, which causes **df** to display the values in a human-readable format:

```
df -h
```

For instance:

```
~]$ df -h
Filesystem                     Size  Used Avail Use% Mounted on
rootfs                          19G  4.4G   14G  25% /
devtmpfs                       362M     0  362M   0% /dev
tmpfs                          373M  256K  372M   1% /dev/shm
tmpfs                          373M  3.0M  370M   1% /run
/dev/mapper/vg_fedora-lv_root   19G  4.4G   14G  25% /
tmpfs                          373M     0  373M   0% /sys/fs/cgroup
tmpfs                          373M     0  373M   0% /media
/dev/vda1                      497M   84M  389M  18% /boot
```

Note that the **/dev/shm** entry represents the system's virtual memory file system, **/sys/fs/cgroup** is a cgroup file system, and **/run** contains information about the running system.

For a complete list of available command line options, refer to the **df**(1) manual page.

17.4.6. Using the du Command

The **du** command allows you to displays the amount of space that is being used by files in a directory. To display the disk usage for each of the subdirectories in the current working directory, run the command with no additional command line options:

```
du
```

For example:

```
~]$ du
8       ./.gconf/apps/gnome-terminal/profiles/Default
12      ./.gconf/apps/gnome-terminal/profiles
16      ./.gconf/apps/gnome-terminal
[output truncated]
460     ./.gimp-2.6
68828   .
```

By default, the **du** command displays the disk usage in kilobytes. To view the information in megabytes and gigabytes, supply the **-h** command line option, which causes the utility to display the values in a human-readable format:

```
du -h
```

For instance:

```
~]$ du -h
8.0K    ./.gconf/apps/gnome-terminal/profiles/Default
12K     ./.gconf/apps/gnome-terminal/profiles
16K     ./.gconf/apps/gnome-terminal
[output truncated]
460K    ./.gimp-2.6
68M     .
```

At the end of the list, the **du** command always shows the grand total for the current directory. To display only this information, supply the **-s** command line option:

```
du -sh
```

For example:

```
~]$ du -sh
68M     .
```

For a complete list of available command line options, refer to the **du**(1) manual page.

17.4.7. Using the System Monitor Tool

The **File Systems** tab of the **System Monitor** tool allows you to view file systems and disk space usage in the graphical user interface.

To start the **System Monitor** tool, either select **Applications**□□□ **System Tools**□□□ **System Monitor** from the **Activities** menu, or type **gnome-system-monitor** at a shell prompt. Then click the **File Systems** tab to view a list of file systems.

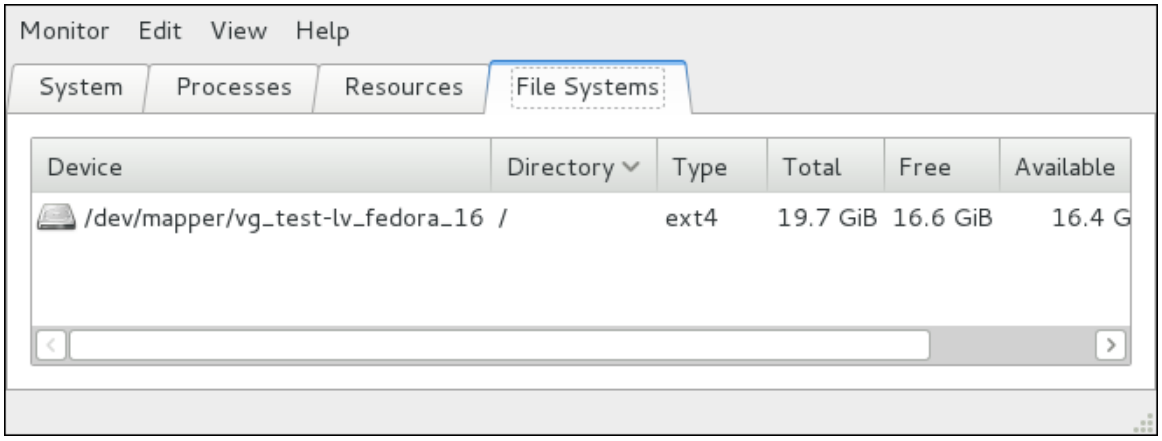


Figure 17.4. System Monitor — File Systems

For each listed file system, the **System Monitor** tool displays the source device (**Device**), target mount point (**Directory**), and file system type (**Type**), as well as its size (**Total**) and how much space is free (**Free**), available (**Available**), and used (**Used**).

17.5. Viewing Hardware Information

17.5.1. Using the lspci Command

The **lspci** command lists all PCI devices that are present in the system:

```
lspci
```

For example:

```
~]$ lspci
00:00.0 Host bridge: Intel Corporation 82X38/X48 Express DRAM Controller
00:01.0 PCI bridge: Intel Corporation 82X38/X48 Express Host-Primary PCI Express Bridge
00:1a.0 USB Controller: Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #4 (rev
 02)
00:1a.1 USB Controller: Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #5 (rev
 02)
00:1a.2 USB Controller: Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #6 (rev
 02)
[output truncated]
```

You can also use the **-v** command line option to display more verbose output, or **-vv** for very verbose output:

```
lspci -v|-vv
```

For instance, to determine the manufacturer, model, and memory size of a system's video card, type:

```
~]$ lspci -v
[output truncated]

01:00.0 VGA compatible controller: nVidia Corporation G84 [Quadro FX 370] (rev a1) (prog-if
 00 [VGA controller])
```

```
        Subsystem: nVidia Corporation Device 0491
        Physical Slot: 2
        Flags: bus master, fast devsel, latency 0, IRQ 16
        Memory at f2000000 (32-bit, non-prefetchable) [size=16M]
        Memory at e0000000 (64-bit, prefetchable) [size=256M]
        Memory at f0000000 (64-bit, non-prefetchable) [size=32M]
        I/O ports at 1100 [size=128]
        Expansion ROM at <unassigned> [disabled]
        Capabilities: <access denied>
        Kernel driver in use: nouveau
        Kernel modules: nouveau, nvidiafb

[output truncated]
```

For a complete list of available command line options, refer to the **lspci**(8) manual page.

17.5.2. Using the lsusb Command

The **lsusb** command allows you to display information about USB buses and devices that are attached to them. To list all USB devices that are in the system, type the following at a shell prompt:

```
lsusb
```

This displays a simple list of devices, for example:

```
~]$ lsusb
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 002 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
[output truncated]
Bus 001 Device 002: ID 0bda:0151 Realtek Semiconductor Corp. Mass Storage Device (Multicard
 Reader)
Bus 008 Device 002: ID 03f0:2c24 Hewlett-Packard Logitech M-UAL-96 Mouse
Bus 008 Device 003: ID 04b3:3025 IBM Corp.
```

You can also use the **-v** command line option to display more verbose output:

```
lsusb -v
```

For instance:

```
~]$ lsusb -v
[output truncated]

Bus 008 Device 002: ID 03f0:2c24 Hewlett-Packard Logitech M-UAL-96 Mouse
Device Descriptor:
  bLength                18
  bDescriptorType         1
  bcdUSB               2.00
  bDeviceClass            0 (Defined at Interface level)
  bDeviceSubClass         0
  bDeviceProtocol         0
  bMaxPacketSize0         8
  idVendor           0x03f0 Hewlett-Packard
  idProduct          0x2c24 Logitech M-UAL-96 Mouse
  bcdDevice           31.00
  iManufacturer           1
  iProduct                2
  iSerial                 0
  bNumConfigurations      1
```

```
  Configuration Descriptor:
    bLength                 9
    bDescriptorType         2
[output truncated]
```

For a complete list of available command line options, refer to the **lsusb**(8) manual page.

17.5.3. Using the lspcmcia Command

The **lspcmcia** command allows you to list all PCMCIA devices that are present in the system. To do so, type the following at a shell prompt:

```
lspcmcia
```

For example:

```
~]$ lspcmcia
Socket 0 Bridge:        [yenta_cardbus]         (bus ID: 0000:15:00.0)
```

You can also use the **-v** command line option to display more verbose information, or **-vv** to increase the verbosity level even further:

```
lspcmcia -v|-vv
```

For instance:

```
~]$ lspcmcia -v
Socket 0 Bridge:        [yenta_cardbus]         (bus ID: 0000:15:00.0)
        Configuration:  state: on       ready: unknown
```

For a complete list of available command line options, refer to the **pccardctl**(8) manual page.

17.5.4. Using the lscpu Command

The **lscpu** command allows you to list information about CPUs that are present in the system, including the number of CPUs, their architecture, vendor, family, model, CPU caches, etc. To do so, type the following at a shell prompt:

```
lscpu
```

For example:

```
~]$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Thread(s) per core:    1
Core(s) per socket:    4
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
```

```
CPU family:            6
Model:                 23
Stepping:              7
CPU MHz:               1998.000
BogoMIPS:              4999.98
Virtualization:        VT-x
L1d cache:             32K
L1i cache:             32K
L2 cache:              3072K
NUMA node0 CPU(s):     0-3
```

For a complete list of available command line options, refer to the **lscpu**(1) manual page.

17.6. Monitoring Performance with Net-SNMP

Fedora 17 includes the **Net-SNMP** software suite, which includes a flexible and extensible *Simple Network Management Protocol* (SNMP) agent. This agent and its associated utilities can be used to provide performance data from a large number of systems to a variety of tools which support polling over the SNMP protocol.

This section provides information on configuring the Net-SNMP agent to securely provide performance data over the network, retrieving the data using the SNMP protocol, and extending the SNMP agent to provide custom performance metrics.

17.6.1. Installing Net-SNMP

The Net-SNMP software suite is available as a set of RPM packages in the Fedora software distribution. *Table 17.2, "Available Net-SNMP packages"* summarizes each of the packages and their contents.

Table 17.2. Available Net-SNMP packages

Package	Provides
net-snmp	The SNMP Agent Daemon and documentation. This package is required for exporting performance data.
net-snmp-libs	The **netsnmp** library and the bundled management information bases (MIBs). This package is required for exporting performance data.
net-snmp-utils	SNMP clients such as **snmpget** and **snmpwalk**. This package is required in order to query a system's performance data over SNMP.
net-snmp-perl	The **mib2c** utility and the **NetSNMP** Perl module.
net-snmp-python	An SNMP client library for Python.

To install any of these packages, use the **yum** command in the following form:

```
yum install package…
```

For example, to install the SNMP Agent Daemon and SNMP clients used in the rest of this section, type the following at a shell prompt:

```
~]# yum install net-snmp net-snmp-libs net-snmp-utils
```

Note that you must have superuser privileges (that is, you must be logged in as `root`) to run this command. For more information on how to install new packages in Fedora, refer to *Section 4.2.4, "Installing Packages"*.

17.6.2. Running the Net-SNMP Daemon

The *net-snmp* package contains `snmpd`, the SNMP Agent Daemon. This section provides information on how to start, stop, and restart the `snmpd` service, and shows how to enable or disable it in the `multi-user` target unit. For more information on the concept of target units and how to manage system services in Fedora in general, refer to *Chapter 8, Services and Daemons*.

17.6.2.1. Starting the Service

To run the `snmpd` service in the current session, type the following at a shell prompt as `root`:

```
systemctl start snmpd.service
```

To configure the service to be automatically started at boot time, use the following command:

```
systemctl enable snmpd.service
```

This will enable the service in the `multi-user` target unit.

17.6.2.2. Stopping the Service

To stop the running `snmpd` service, type the following at a shell prompt as `root`:

```
systemctl stop snmpd.service
```

To disable starting the service at boot time, use the following command:

```
systemctl disable snmpd.service
```

This will disable the service in the `multi-user` target unit.

17.6.2.3. Restarting the Service

To restart the running `snmpd` service, type the following at a shell prompt:

```
systemctl restart snmpd.service
```

This will stop the service and start it again in quick succession. To only reload the configuration without stopping the service, run the following command instead:

```
systemctl reload snmpd.service
```

This will cause the running `snmpd` service to reload the configuration.

17.6.3. Configuring Net-SNMP

To change the Net-SNMP Agent Daemon configuration, edit the **`/etc/snmp/snmpd.conf`** configuration file. The default **`snmpd.conf`** file shipped with Fedora 17 is heavily commented and serves as a good starting point for agent configuration.

This section focuses on two common tasks: setting system information and configuring authentication. For more information about available configuration directives, refer to the **snmpd.conf**(5) manual page. Additionally, there is a utility in the *net-snmp* package named **`snmpconf`** which can be used to interactively generate a valid agent configuration.

Note that the *net-snmp-utils* package must be installed in order to use the **snmpwalk** utility described in this section.



Applying the changes

For any changes to the configuration file to take effect, force the `snmpd` service to re-read the configuration by running the following command as `root`:

```
systemctl reload snmpd.service
```

17.6.3.1. Setting System Information

Net-SNMP provides some rudimentary system information via the `system` tree. For example, the following **snmpwalk** command shows the `system` tree with a default agent configuration.

```
~]# snmpwalk -v2c -c public localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP Wed
 Mar 9 23:54:34 EST 2011 x86_64
SNMPv2-MIB::sysObjectID.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.10
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (99554) 0:16:35.54
SNMPv2-MIB::sysContact.0 = STRING: Root <root@localhost> (configure /etc/snmp/
snmp.local.conf)
SNMPv2-MIB::sysName.0 = STRING: localhost.localdomain
SNMPv2-MIB::sysLocation.0 = STRING: Unknown (edit /etc/snmp/snmpd.conf)
```

By default, the `sysName` object is set to the hostname. The `sysLocation` and `sysContact` objects can be configured in the **/etc/snmp/snmpd.conf** file by changing the value of the **syslocation** and **syscontact** directives, for example:

```
syslocation Datacenter, Row 3, Rack 2
syscontact UNIX Admin <admin@example.com>
```

After making changes to the configuration file, reload the configuration and test it by running the **snmpwalk** command again:

```
~]# systemct reload snmpd.service
~]# snmpwalk -v2c -c public localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP Wed
 Mar 9 23:54:34 EST 2011 x86_64
SNMPv2-MIB::sysObjectID.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.10
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (158357) 0:26:23.57
SNMPv2-MIB::sysContact.0 = STRING: UNIX Admin <admin@example.com>
SNMPv2-MIB::sysName.0 = STRING: localhost.localdomain
SNMPv2-MIB::sysLocation.0 = STRING: Datacenter, Row 3, Rack 2
```

17.6.3.2. Configuring Authentication

The Net-SNMP Agent Daemon supports all three versions of the SNMP protocol. The first two versions (1 and 2c) provide for simple authentication using a *community string*. This string is a shared secret between the agent and any client utilities. The string is passed in clear text over the network however and is not considered secure. Version 3 of the SNMP protocol supports user authentication and message encryption using a variety of protocols. The Net-SNMP agent also supports tunneling over SSH, TLS authentication with X.509 certificates, and Kerberos authentication.

Configuring SNMP Version 2c Community

To configure an **SNMP version 2c community**, use either the **rocommunity** or **rwcommunity** directive in the **/etc/snmp/snmpd.conf** configuration file. The format of the directives is the following:

```
directive community [source [OID]]
```

… where *community* is the community string to use, *source* is an IP address or subnet, and *OID* is the SNMP tree to provide access to. For example, the following directive provides read-only access to the `system` tree to a client using the community string “redhat” on the local machine:

```
rocommunity redhat 127.0.0.1 .1.3.6.1.2.1.1
```

To test the configuration, use the **snmpwalk** command with the **-v** and **-c** options.

```
~]# snmpwalk -v2c -c redhat localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP Wed
 Mar 9 23:54:34 EST 2011 x86_64
SNMPv2-MIB::sysObjectID.0 = OID: NET-SNMP-MIB::netSnmpAgentOIDs.10
DISMAN-EVENT-MIB::sysUpTimeInstance = Timeticks: (158357) 0:26:23.57
SNMPv2-MIB::sysContact.0 = STRING: UNIX Admin <admin@example.com>
SNMPv2-MIB::sysName.0 = STRING: localhost.localdomain
SNMPv2-MIB::sysLocation.0 = STRING: Datacenter, Row 3, Rack 2
```

Configuring SNMP Version 3 User

To configure an **SNMP version 3 user**, use the **net-snmp-create-v3-user** command. This command adds entries to the **/var/lib/net-snmp/snmpd.conf** and **/etc/snmp/snmpd.conf** files which create the user and grant access to the user. Note that the **net-snmp-create-v3-user** command may only be run when the agent is not running. The following example creates the “sysadmin” user with the password “redhatsnmp”:

```
~]# systemctl stop snmpd.service
~]# net-snmp-create-v3-user
Enter a SNMPv3 user name to create:
admin
Enter authentication pass-phrase:
redhatsnmp
Enter encryption pass-phrase:
  [press return to reuse the authentication pass-phrase]

adding the following line to /var/lib/net-snmp/snmpd.conf:
   createUser admin MD5 "redhatsnmp" DES
adding the following line to /etc/snmp/snmpd.conf:
   rwuser admin
~]# systemctl start snmpd.service
```

The **rwuser** directive (or **rouser** when the **-ro** command line option is supplied) that **net-snmp-create-v3-user** adds to **/etc/snmp/snmpd.conf** has a similar format to the **rwcommunity** and **rocommunity** directives:

```
directive user [noauth|auth|priv] [OID]
```

… where *user* is a username and *OID* is the SNMP tree to provide access to. By default, the Net-SNMP Agent Daemon allows only authenticated requests (the **auth** option). The **noauth** option allows you to permit unauthenticated requests, and the **priv** option enforces the use of encryption. The **authpriv** option specifies that requests must be authenticated and replies should be encrypted.

For example, the following line grants the user “admin” read-write access to the entire tree:

```
rwuser admin authpriv .1
```

To test the configuration, create a **.snmp** directory in your user's home directory and a configuration file named **snmp.conf** in that directory (**~/.snmp/snmp.conf**) with the following lines:

```
defVersion 3
defSecurityLevel authPriv
defSecurityName admin
defPassphrase redhatsnmp
```

The **snmpwalk** command will now use these authentication settings when querying the agent:

```
~]$ snmpwalk -v3 localhost system
SNMPv2-MIB::sysDescr.0 = STRING: Linux localhost.localdomain 2.6.32-122.el6.x86_64 #1 SMP Wed
 Mar 9 23:54:34 EST 2011 x86_64
[output truncated]
```

17.6.4. Retrieving Performance Data over SNMP

The Net-SNMP Agent in Fedora provides a wide variety of performance information over the SNMP protocol. In addition, the agent can be queried for a listing of the installed RPM packages on the system, a listing of currently running processes on the system, or the network configuration of the system.

This section provides an overview of OIDs related to performance tuning available over SNMP. It assumes that the *net-snmp-utils* package is installed and that the user is granted access to the SNMP tree as described in *Section 17.6.3.2, “Configuring Authentication”*.

17.6.4.1. Hardware Configuration

The `Host Resources MIB` included with Net-SNMP presents information about the current hardware and software configuration of a host to a client utility. *Table 17.3, “Available OIDs”* summarizes the different OIDs available under that MIB.

Table 17.3. Available OIDs

OID	Description
`HOST-RESOURCES-MIB::hrSystem`	Contains general system information such as uptime, number of users, and number of running processes.
`HOST-RESOURCES-MIB::hrStorage`	Contains data on memory and file system usage.
`HOST-RESOURCES-MIB::hrDevices`	Contains a listing of all processors, network devices, and file systems.
`HOST-RESOURCES-MIB::hrSWRun`	Contains a listing of all running processes.
`HOST-RESOURCES-MIB::hrSWRunPerf`	Contains memory and CPU statistics on the process table from HOST-RESOURCES-MIB::hrSWRun.
`HOST-RESOURCES-MIB::hrSWInstalled`	Contains a listing of the RPM database.

There are also a number of SNMP tables available in the Host Resources MIB which can be used to retrieve a summary of the available information. The following example displays `HOST-RESOURCES-MIB::hrFSTable`:

```
~]$ snmptable -Cb localhost HOST-RESOURCES-MIB::hrFSTable
SNMP table: HOST-RESOURCES-MIB::hrFSTable

 Index MountPoint RemoteMountPoint                                Type
    Access Bootable StorageIndex LastFullBackupDate LastPartialBackupDate
     1        "/"                "" HOST-RESOURCES-TYPES::hrFSLinuxExt2
 readWrite     true           31      0-1-1,0:0:0.0         0-1-1,0:0:0.0
     5 "/dev/shm"                ""     HOST-RESOURCES-TYPES::hrFSOther
 readWrite    false           35      0-1-1,0:0:0.0         0-1-1,0:0:0.0
     6    "/boot"                "" HOST-RESOURCES-TYPES::hrFSLinuxExt2
 readWrite    false           36      0-1-1,0:0:0.0         0-1-1,0:0:0.0
```

For more information about `HOST-RESOURCES-MIB`, see the **`/usr/share/snmp/mibs/HOST-RESOURCES-MIB.txt`** file.

17.6.4.2. CPU and Memory Information

Most system performance data is available in the `UCD SNMP MIB`. The `systemStats` OID provides a number of counters around processor usage:

```
~]$ snmpwalk localhost UCD-SNMP-MIB::systemStats
UCD-SNMP-MIB::ssIndex.0 = INTEGER: 1
UCD-SNMP-MIB::ssErrorName.0 = STRING: systemStats
UCD-SNMP-MIB::ssSwapIn.0 = INTEGER: 0 kB
UCD-SNMP-MIB::ssSwapOut.0 = INTEGER: 0 kB
UCD-SNMP-MIB::ssIOSent.0 = INTEGER: 0 blocks/s
UCD-SNMP-MIB::ssIOReceive.0 = INTEGER: 0 blocks/s
UCD-SNMP-MIB::ssSysInterrupts.0 = INTEGER: 29 interrupts/s
UCD-SNMP-MIB::ssSysContext.0 = INTEGER: 18 switches/s
UCD-SNMP-MIB::ssCpuUser.0 = INTEGER: 0
UCD-SNMP-MIB::ssCpuSystem.0 = INTEGER: 0
UCD-SNMP-MIB::ssCpuIdle.0 = INTEGER: 99
UCD-SNMP-MIB::ssCpuRawUser.0 = Counter32: 2278
UCD-SNMP-MIB::ssCpuRawNice.0 = Counter32: 1395
UCD-SNMP-MIB::ssCpuRawSystem.0 = Counter32: 6826
UCD-SNMP-MIB::ssCpuRawIdle.0 = Counter32: 3383736
UCD-SNMP-MIB::ssCpuRawWait.0 = Counter32: 7629
UCD-SNMP-MIB::ssCpuRawKernel.0 = Counter32: 0
UCD-SNMP-MIB::ssCpuRawInterrupt.0 = Counter32: 434
UCD-SNMP-MIB::ssIORawSent.0 = Counter32: 266770
UCD-SNMP-MIB::ssIORawReceived.0 = Counter32: 427302
UCD-SNMP-MIB::ssRawInterrupts.0 = Counter32: 743442
UCD-SNMP-MIB::ssRawContexts.0 = Counter32: 718557
UCD-SNMP-MIB::ssCpuRawSoftIRQ.0 = Counter32: 128
UCD-SNMP-MIB::ssRawSwapIn.0 = Counter32: 0
UCD-SNMP-MIB::ssRawSwapOut.0 = Counter32: 0
```

In particular, the `ssCpuRawUser`, `ssCpuRawSystem`, `ssCpuRawWait`, and `ssCpuRawIdle` OIDs provide counters which are helpful when determining whether a system is spending most of its processor time in kernel space, user space, or I/O. `ssRawSwapIn` and `ssRawSwapOut` can be helpful when determining whether a system is suffering from memory exhaustion.

More memory information is available under the `UCD-SNMP-MIB::memory` OID, which provides similar data to the **`free`** command:

```
~]$ snmpwalk localhost UCD-SNMP-MIB::memory
UCD-SNMP-MIB::memIndex.0 = INTEGER: 0
UCD-SNMP-MIB::memErrorName.0 = STRING: swap
UCD-SNMP-MIB::memTotalSwap.0 = INTEGER: 1023992 kB
UCD-SNMP-MIB::memAvailSwap.0 = INTEGER: 1023992 kB
UCD-SNMP-MIB::memTotalReal.0 = INTEGER: 1021588 kB
```

```
UCD-SNMP-MIB::memAvailReal.0 = INTEGER: 634260 kB
UCD-SNMP-MIB::memTotalFree.0 = INTEGER: 1658252 kB
UCD-SNMP-MIB::memMinimumSwap.0 = INTEGER: 16000 kB
UCD-SNMP-MIB::memBuffer.0 = INTEGER: 30760 kB
UCD-SNMP-MIB::memCached.0 = INTEGER: 216200 kB
UCD-SNMP-MIB::memSwapError.0 = INTEGER: noError(0)
UCD-SNMP-MIB::memSwapErrorMsg.0 = STRING:
```

Load averages are also available in the `UCD SNMP MIB`. The SNMP table `UCD-SNMP-MIB::laTable` has a listing of the 1, 5, and 15 minute load averages:

```
~]$ snmptable localhost UCD-SNMP-MIB::laTable
SNMP table: UCD-SNMP-MIB::laTable

 laIndex laNames laLoad laConfig laLoadInt laLoadFloat laErrorFlag laErrMessage
       1  Load-1   0.00    12.00         0    0.000000     noError
       2  Load-5   0.00    12.00         0    0.000000     noError
       3 Load-15   0.00    12.00         0    0.000000     noError
```

17.6.4.3. File System and Disk Information

The `Host Resources MIB` provides information on file system size and usage. Each file system (and also each memory pool) has an entry in the `HOST-RESOURCES-MIB::hrStorageTable` table:

```
~]$ snmptable -Cb localhost HOST-RESOURCES-MIB::hrStorageTable
SNMP table: HOST-RESOURCES-MIB::hrStorageTable

 Index                                       Type           Descr
AllocationUnits    Size   Used AllocationFailures
     1           HOST-RESOURCES-TYPES::hrStorageRam Physical memory
1024 Bytes 1021588 388064                 ?
     3 HOST-RESOURCES-TYPES::hrStorageVirtualMemory  Virtual memory
1024 Bytes 2045580 388064                 ?
     6         HOST-RESOURCES-TYPES::hrStorageOther  Memory buffers
1024 Bytes 1021588  31048                 ?
     7         HOST-RESOURCES-TYPES::hrStorageOther   Cached memory
1024 Bytes  216604 216604                 ?
    10 HOST-RESOURCES-TYPES::hrStorageVirtualMemory      Swap space
1024 Bytes 1023992      0                 ?
    31     HOST-RESOURCES-TYPES::hrStorageFixedDisk               /
4096 Bytes 2277614 250391                 ?
    35     HOST-RESOURCES-TYPES::hrStorageFixedDisk        /dev/shm
4096 Bytes  127698      0                 ?
    36     HOST-RESOURCES-TYPES::hrStorageFixedDisk           /boot
1024 Bytes  198337  26694                 ?
```

The OIDs under `HOST-RESOURCES-MIB::hrStorageSize` and `HOST-RESOURCES-MIB::hrStorageUsed` can be used to calculate the remaining capacity of each mounted file system.

I/O data is available both in `UCD-SNMP-MIB::systemStats` (`ssIORawSent.0` and `ssIORawRecieved.0`) and in `UCD-DISKIO-MIB::diskIOTable`. The latter provides much more granular data. Under this table are OIDs for `diskIONReadX` and `diskIONWrittenX`, which provide counters for the number of bytes read from and written to the block device in question since the system boot:

```
~]$ snmptable -Cb localhost UCD-DISKIO-MIB::diskIOTable
SNMP table: UCD-DISKIO-MIB::diskIOTable

 Index Device     NRead  NWritten Reads Writes LA1 LA5 LA15    NReadX NWrittenX
...
```

```
    25    sda 216886272 139109376 16409   4894   ?   ?    ? 216886272 139109376
    26   sda1   2455552      5120   613      2   ?   ?    ?   2455552      5120
    27   sda2   1486848         0   332      0   ?   ?    ?   1486848         0
    28   sda3 212321280 139104256 15312   4871   ?   ?    ? 212321280 139104256
```

17.6.4.4. Network Information

Information on network devices is provided by the Interfaces MIB. `IF-MIB::ifTable` provides an SNMP table with an entry for each interface on the system, the configuration of the interface, and various packet counters for the interface. The following example shows the first few columns of `ifTable` on a system with two physical network interfaces:

```
~]$ snmptable -Cb localhost IF-MIB::ifTable
SNMP table: IF-MIB::ifTable

 Index Descr             Type    Mtu    Speed      PhysAddress AdminStatus
     1    lo softwareLoopback 16436 10000000                          up
     2  eth0   ethernetCsmacd  1500        0 52:54:0:c7:69:58          up
     3  eth1   ethernetCsmacd  1500        0 52:54:0:a7:a3:24        down
```

Network traffic is available under the OIDs `IF-MIB::ifOutOctets` and `IF-MIB::ifInOctets`. The following SNMP queries will retrieve network traffic for each of the interfaces on this system:

```
~]$ snmpwalk localhost IF-MIB::ifDescr
IF-MIB::ifDescr.1 = STRING: lo
IF-MIB::ifDescr.2 = STRING: eth0
IF-MIB::ifDescr.3 = STRING: eth1
~]$ snmpwalk localhost IF-MIB::ifOutOctets
IF-MIB::ifOutOctets.1 = Counter32: 10060699
IF-MIB::ifOutOctets.2 = Counter32: 650
IF-MIB::ifOutOctets.3 = Counter32: 0
~]$ snmpwalk localhost IF-MIB::ifInOctets
IF-MIB::ifInOctets.1 = Counter32: 10060699
IF-MIB::ifInOctets.2 = Counter32: 78650
IF-MIB::ifInOctets.3 = Counter32: 0
```

17.6.5. Extending Net-SNMP

The Net-SNMP Agent can be extended to provide application metrics in addition to raw system metrics. This allows for capacity planning as well as performance issue troubleshooting. For example, it may be helpful to know that an email system had a 5-minute load average of 15 while being tested, but it is more helpful to know that the email system has a load average of 15 while processing 80,000 messages a second. When application metrics are available via the same interface as the system metrics, this also allows for the visualization of the impact of different load scenarios on system performance (for example, each additional 10,000 messages increases the load average linearly until 100,000).

A number of the applications that ship with Fedora extend the Net-SNMP Agent to provide application metrics over SNMP. There are several ways to extend the agent for custom applications as well. This section describes extending the agent with shell scripts and Perl plug-ins. It assumes that the *net-snmp-utils* and *net-snmp-perl* packages are installed, and that the user is granted access to the SNMP tree as described in *Section 17.6.3.2, "Configuring Authentication"*.

17.6.5.1. Extending Net-SNMP with Shell Scripts

The Net-SNMP Agent provides an extension MIB (`NET-SNMP-EXTEND-MIB`) that can be used to query arbitrary shell scripts. To specify the shell script to run, use the **`extend`** directive in the `/`

etc/snmp/snmpd.conf file. Once defined, the Agent will provide the exit code and any output of the command over SNMP. The example below demonstrates this mechanism with a script which determines the number of `httpd` processes in the process table.



Using the proc directive

The Net-SNMP Agent also provides a built-in mechanism for checking the process table via the **proc** directive. Refer to the **snmpd.conf**(5) manual page for more information.

The exit code of the following shell script is the number of **httpd** processes running on the system at a given point in time:

```
#!/bin/sh

NUMPIDS=`pgrep httpd | wc -l`

exit $NUMPIDS
```

To make this script available over SNMP, copy the script to a location on the system path, set the executable bit, and add an **extend** directive to the **/etc/snmp/snmpd.conf** file. The format of the **extend** directive is the following:

```
extend name prog args
```

… where *name* is an identifying string for the extension, *prog* is the program to run, and *args* are the arguments to give the program. For instance, if the above shell script is copied to **/usr/local/bin/check_apache.sh**, the following directive will add the script to the SNMP tree:

```
extend httpd_pids /bin/sh /usr/local/bin/check_apache.sh
```

The script can then be queried at `NET-SNMP-EXTEND-MIB::nsExtendObjects`:

```
~]$ snmpwalk localhost NET-SNMP-EXTEND-MIB::nsExtendObjects
NET-SNMP-EXTEND-MIB::nsExtendNumEntries.0 = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendCommand."httpd_pids" = STRING: /bin/sh
NET-SNMP-EXTEND-MIB::nsExtendArgs."httpd_pids" = STRING: /usr/local/bin/check_apache.sh
NET-SNMP-EXTEND-MIB::nsExtendInput."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendCacheTime."httpd_pids" = INTEGER: 5
NET-SNMP-EXTEND-MIB::nsExtendExecType."httpd_pids" = INTEGER: exec(1)
NET-SNMP-EXTEND-MIB::nsExtendRunType."httpd_pids" = INTEGER: run-on-read(1)
NET-SNMP-EXTEND-MIB::nsExtendStorage."httpd_pids" = INTEGER: permanent(4)
NET-SNMP-EXTEND-MIB::nsExtendStatus."httpd_pids" = INTEGER: active(1)
NET-SNMP-EXTEND-MIB::nsExtendOutput1Line."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendOutputFull."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendOutNumLines."httpd_pids" = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
NET-SNMP-EXTEND-MIB::nsExtendOutLine."httpd_pids".1 = STRING:
```

Note that the exit code (“8” in this example) is provided as an INTEGER type and any output is provided as a STRING type. To expose multiple metrics as integers, supply different arguments to the script using the **extend** directive. For example, the following shell script can be used to determine the number of processes matching an arbitrary string, and will also output a text string giving the number of processes:

```
#!/bin/sh

PATTERN=$1
NUMPIDS=`pgrep $PATTERN | wc -l`

echo "There are $NUMPIDS $PATTERN processes."
exit $NUMPIDS
```

The following **/etc/snmp/snmpd.conf** directives will give both the number of `httpd` PIDs as well as the number of `snmpd` PIDs when the above script is copied to **/usr/local/bin/check_proc.sh**:

```
extend httpd_pids /bin/sh /usr/local/bin/check_proc.sh httpd
extend snmpd_pids /bin/sh /usr/local/bin/check_proc.sh snmpd
```

The following example shows the output of an **snmpwalk** of the `nsExtendObjects` OID:

```
~]$ snmpwalk localhost NET-SNMP-EXTEND-MIB::nsExtendObjects
NET-SNMP-EXTEND-MIB::nsExtendNumEntries.0 = INTEGER: 2
NET-SNMP-EXTEND-MIB::nsExtendCommand."httpd_pids" = STRING: /bin/sh
NET-SNMP-EXTEND-MIB::nsExtendCommand."snmpd_pids" = STRING: /bin/sh
NET-SNMP-EXTEND-MIB::nsExtendArgs."httpd_pids" = STRING: /usr/local/bin/check_proc.sh httpd
NET-SNMP-EXTEND-MIB::nsExtendArgs."snmpd_pids" = STRING: /usr/local/bin/check_proc.sh snmpd
NET-SNMP-EXTEND-MIB::nsExtendInput."httpd_pids" = STRING:
NET-SNMP-EXTEND-MIB::nsExtendInput."snmpd_pids" = STRING:
...
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
NET-SNMP-EXTEND-MIB::nsExtendResult."snmpd_pids" = INTEGER: 1
NET-SNMP-EXTEND-MIB::nsExtendOutLine."httpd_pids".1 = STRING: There are 8 httpd processes.
NET-SNMP-EXTEND-MIB::nsExtendOutLine."snmpd_pids".1 = STRING: There are 1 snmpd processes.
```



Integer exit codes are limited

Integer exit codes are limited to a range of 0–255. For values that are likely to exceed 256, either use the standard output of the script (which will be typed as a string) or a different method of extending the agent.

This last example shows a query for the free memory of the system and the number of `httpd` processes. This query could be used during a performance test to determine the impact of the number of processes on memory pressure:

```
~]$ snmpget localhost \
    'NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids"' \
    UCD-SNMP-MIB::memAvailReal.0
NET-SNMP-EXTEND-MIB::nsExtendResult."httpd_pids" = INTEGER: 8
UCD-SNMP-MIB::memAvailReal.0 = INTEGER: 799664 kB
```

17.6.5.2. Extending Net-SNMP with Perl

Executing shell scripts using the **extend** directive is a fairly limited method for exposing custom application metrics over SNMP. The Net-SNMP Agent also provides an embedded Perl interface for exposing custom objects. The *net-snmp-perl* package provides the **NetSNMP::agent** Perl module that is used to write embedded Perl plug-ins on Fedora.

The **NetSNMP::agent** Perl module provides an **agent** object which is used to handle requests for a part of the agent's OID tree. The **agent** object's constructor has options for running the agent as a sub-agent of snmpd or a standalone agent. No arguments are necessary to create an embedded agent:

```
use NetSNMP::agent (':all');

my $agent = new NetSNMP::agent();
```

The **agent** object has a register method which is used to register a callback function with a particular OID. The register function takes a name, OID, and pointer to the callback function. The following example will register a callback function named hello_handler with the SNMP Agent which will handle requests under the OID **.1.3.6.1.4.1.8072.9999.9999**:

```
$agent->register("hello_world", ".1.3.6.1.4.1.8072.9999.9999",
                 \&hello_handler);
```



Obtaining a root OID

The OID **.1.3.6.1.4.1.8072.9999.9999** (NET-SNMP-MIB::netSnmpPlaypen) is typically used for demonstration purposes only. If your organization does not already have a root OID, you can obtain one by contacting your Name Registration Authority (ANSI in the United States).

The handler function will be called with four parameters, *HANDLER*, *REGISTRATION_INFO*, *REQUEST_INFO*, and *REQUESTS*. The *REQUESTS* parameter contains a list of requests in the current call and should be iterated over and populated with data. The **request** objects in the list have get and set methods which allow for manipulating the OID and value of the request. For example, the following call will set the value of a request object to the string “hello world”:

```
$request->setValue(ASN_OCTET_STR, "hello world");
```

The handler function should respond to two types of SNMP requests: the GET request and the GETNEXT request. The type of request is determined by calling the getMode method on the **request_info** object passed as the third parameter to the handler function. If the request is a GET request, the caller will expect the handler to set the value of the **request** object, depending on the OID of the request. If the request is a GETNEXT request, the caller will also expect the handler to set the OID of the request to the next available OID in the tree. This is illustrated in the following code example:

```
my $request;
my $string_value = "hello world";
my $integer_value = "8675309";

for($request = $requests; $request; $request = $request->next()) {
  my $oid = $request->getOID();
  if ($request_info->getMode() == MODE_GET) {
    if ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
      $request->setValue(ASN_OCTET_STR, $string_value);
    }
    elsif ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.1")) {
      $request->setValue(ASN_INTEGER, $integer_value);
    }
  } elsif ($request_info->getMode() == MODE_GETNEXT) {
```

```
    if ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
      $request->setOID(".1.3.6.1.4.1.8072.9999.9999.1.1");
      $request->setValue(ASN_INTEGER, $integer_value);
    }
    elsif ($oid < new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
      $request->setOID(".1.3.6.1.4.1.8072.9999.9999.1.0");
      $request->setValue(ASN_OCTET_STR, $string_value);
    }
  }
}
```

When `getMode` returns **`MODE_GET`**, the handler analyzes the value of the `getOID` call on the **`request`** object. The value of the **`request`** is set to either `string_value` if the OID ends in ".1.0", or set to `integer_value` if the OID ends in ".1.1". If the `getMode` returns **`MODE_GETNEXT`**, the handler determines whether the OID of the request is ".1.0", and then sets the OID and value for ".1.1". If the request is higher on the tree than ".1.0", the OID and value for ".1.0" is set. This in effect returns the "next" value in the tree so that a program like **`snmpwalk`** can traverse the tree without prior knowledge of the structure.

The type of the variable is set using constants from **`NetSNMP::ASN`**. See the **`perldoc`** for **`NetSNMP::ASN`** for a full list of available constants.

The entire code listing for this example Perl plug-in is as follows:

```
#!/usr/bin/perl

use NetSNMP::agent (':all');
use NetSNMP::ASN qw(ASN_OCTET_STR ASN_INTEGER);

sub hello_handler {
  my ($handler, $registration_info, $request_info, $requests) = @_;
  my $request;
  my $string_value = "hello world";
  my $integer_value = "8675309";

  for($request = $requests; $request; $request = $request->next()) {
    my $oid = $request->getOID();
    if ($request_info->getMode() == MODE_GET) {
      if ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
        $request->setValue(ASN_OCTET_STR, $string_value);
      }
      elsif ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.1")) {
        $request->setValue(ASN_INTEGER, $integer_value);
      }
    } elsif ($request_info->getMode() == MODE_GETNEXT) {
      if ($oid == new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
        $request->setOID(".1.3.6.1.4.1.8072.9999.9999.1.1");
        $request->setValue(ASN_INTEGER, $integer_value);
      }
      elsif ($oid < new NetSNMP::OID(".1.3.6.1.4.1.8072.9999.9999.1.0")) {
        $request->setOID(".1.3.6.1.4.1.8072.9999.9999.1.0");
        $request->setValue(ASN_OCTET_STR, $string_value);
      }
    }
  }
}

my $agent = new NetSNMP::agent();
$agent->register("hello_world", ".1.3.6.1.4.1.8072.9999.9999",
                 \&hello_handler);
```

To test the plug-in, copy the above program to **`/usr/share/snmp/hello_world.pl`** and add the following line to the **`/etc/snmp/snmpd.conf`** configuration file:

```
perl do "/usr/share/snmp/hello_world.pl"
```

The SNMP Agent Daemon will need to be restarted to load the new Perl plug-in. Once it has been restarted, an **snmpwalk** should return the new data:

```
~]$ snmpwalk localhost NET-SNMP-MIB::netSnmpPlaypen
NET-SNMP-MIB::netSnmpPlaypen.1.0 = STRING: "hello world"
NET-SNMP-MIB::netSnmpPlaypen.1.1 = INTEGER: 8675309
```

The **snmpget** should also be used to exercise the other mode of the handler:

```
~]$ snmpget localhost \
    NET-SNMP-MIB::netSnmpPlaypen.1.0 \
    NET-SNMP-MIB::netSnmpPlaypen.1.1
NET-SNMP-MIB::netSnmpPlaypen.1.0 = STRING: "hello world"
NET-SNMP-MIB::netSnmpPlaypen.1.1 = INTEGER: 8675309
```

17.7. Additional Resources

To learn more about gathering system information, refer to the following resources.

17.7.1. Installed Documentation

- **ps**(1) — The manual page for the **ps** command.
- **top**(1) — The manual page for the **top** command.
- **free**(1) — The manual page for the **free** command.
- **df**(1) — The manual page for the **df** command.
- **du**(1) — The manual page for the **du** command.
- **lspci**(8) — The manual page for the **lspci** command.
- **snmpd**(8) — The manual page for the `snmpd` service.
- **snmpd.conf**(5) — The manual page for the **/etc/snmp/snmpd.conf** file containing full documentation of available configuration directives.

Viewing and Managing Log Files

Log files are files that contain messages about the system, including the kernel, services, and applications running on it. There are different log files for different information. For example, there is a default system log file, a log file just for security messages, and a log file for cron tasks.

Log files can be very useful when trying to troubleshoot a problem with the system such as trying to load a kernel driver or when looking for unauthorized login attempts to the system. This chapter discusses where to find log files, how to view log files, and what to look for in log files.

Some log files are controlled by a daemon called `rsyslogd`. A list of log files maintained by `rsyslogd` can be found in the **`/etc/rsyslog.conf`** configuration file.

rsyslog is an enhanced, multi-threaded syslog daemon which replaced the **sysklogd** daemon. **rsyslog** supports the same functionality as **sysklogd** and extends it with enhanced filtering, encryption protected relaying of messages, various configuration options, or support for transportation via the TCP or UDP protocols. Note that **rsyslog** is compatible with **sysklogd**.

18.1. Configuring rsyslog

The main configuration file for **rsyslog** is **`/etc/rsyslog.conf`**. It consists of *global directives*, *rules* or comments (any empty lines or any text following a hash sign (#)). Both, global directives and rules are extensively described in the sections below.

18.1.1. Global Directives

Global directives specify configuration options that apply to the `rsyslogd` daemon. They usually specify a value for a specific pre-defined variable that affects the behavior of the `rsyslogd` daemon or a rule that follows. All of the global directives must start with a dollar sign (**$**). Only one directive can be specified per line. The following is an example of a global directive that specifies the maximum size of the syslog message queue:

```
$MainMsgQueueSize 50000
```

The default size defined for this directive (`10,000` messages) can be overridden by specifying a different value (as shown in the example above).

You may define multiple directives in your **`/etc/rsyslog.conf`** configuration file. A directive affects the behavior of all configuration options until another occurrence of that same directive is detected.

A comprehensive list of all available configuration directives and their detailed description can be found in **`/usr/share/doc/rsyslog-<version-number>/rsyslog_conf_global.html`**.

18.1.2. Modules

Due to its modular design, **rsyslog** offers a variety of *modules* which provide dynamic functionality. Note that modules can be written by third parties. Most modules provide additional inputs (see *Input Modules* below) or outputs (see *Output Modules* below). Other modules provide special functionality specific to each module. The modules may provide additional configuration directives that become available after a module is loaded. To load a module, use the following syntax:

```
$ModLoad <MODULE>
```

where **$ModLoad** is the global directive that loads the specified module and <*MODULE*> represents your desired module. For example, if you want to load the **Text File Input Module** (**imfile** — enables **rsyslog** to convert any standard text files into syslog messages), specify the following line in your **/etc/rsyslog.conf** configuration file:

```
$ModLoad imfile
```

rsyslog offers a number of modules which are split into these main categories:

- Input Modules — Input modules gather messages from various sources. The name of an input module always starts with the **im** prefix, such as **imfile**, **imrelp**, etc.
- Output Modules — Output modules provide a facility to store messages into various targets such as sending them across network, storing them in a database or encrypting them. The name of an output module always starts with the **om** prefix, such as **omsnmp**, **omrelp**, etc.
- Filter Modules — Filter modules provide the ability to filter messages according to specified rules. The name of a filter module always starts with the **fm** prefix.
- Parser Modules — Parser modules use the message parsers to parse message content of any received messages. The name of a parser module always starts with the **pm** prefix, such as **pmrfc5424**, **pmrfc3164**, etc.
- Message Modification Modules — Message modification modules change the content of a syslog message. The message modification modules only differ in their implementation from the output and filter modules but share the same interface.
- String Generator Modules — String generator modules generate strings based on the message content and strongly cooperate with the template feature provided by **rsyslog**. For more information on templates, refer to *Section 18.1.3.3, "Templates"*. The name of a string generator module always starts with the **sm** prefix, such as **smfile**, **smtradfile**, etc.
- Library Modules — Library modules generally provide functionality for other loadable modules. These modules are loaded automatically by **rsyslog** when needed and cannot be configured by the user.

A comprehensive list of all available modules and their detailed description can be found at *http://www.rsyslog.com/doc/rsyslog_conf_modules.html*[1]

Make sure you use trustworthy modules only

Note that when **rsyslog** loads any modules, it provides them with access to some of its functions and data. This poses a possible security threat. To minimize security risks, use trustworthy modules only.

18.1.3. Rules

A rule is specified by a *filter* part, which selects a subset of syslog messages, and an *action* part, which specifies what to do with the selected messages. To define a rule in your **/etc/**

[1] http://www.rsyslog.com/doc/rsyslog_conf_modules.html/

rsyslog.conf configuration file, define both, a filter and an action, on one line and separate them with one or more spaces or tabs. For more information on filters, refer to *Section 18.1.3.1, "Filter Conditions"* and for information on actions, refer to *Section 18.1.3.2, "Actions"*.

18.1.3.1. Filter Conditions

rsyslog offers various ways how to filter syslog messages according to various properties. This sections sums up the most used filter conditions.

Facility/Priority-based filters

The most used and well-known way to filter syslog messages is to use the facility/priority-based filters which filter syslog messages based on two conditions: *facility* and *priority*. To create a selector, use the following syntax:

```
<FACILITY>.<PRIORITY>
```

where:

- <*FACILITY*> specifies the subsystem that produces a specific syslog message. For example, the **mail** subsystem handles all mail related syslog messages. <*FACILITY*> can be represented by one of these keywords: **auth**, **authpriv**, **cron**, **daemon**, **kern**, **lpr**, **mail**, **news**, **syslog**, **user**, **uucp**, and **local0** through **local7**.

- <*PRIORITY*> specifies a priority of a syslog message. <*PRIORITY*> can be represented by one of these keywords (listed in an ascending order): **debug**, **info**, **notice**, **warning**, **err**, **crit**, **alert**, and **emerg**.

  By preceding any priority with an equal sign (**=**), you specify that only syslog messages with that priority will be selected. All other priorities will be ignored. Conversely, preceding a priority with an exclamation mark (**!**) selects all syslog messages but those with the defined priority. By not using either of these two extensions, you specify a selection of syslog messages with the defined or higher priority.

In addition to the keywords specified above, you may also use an asterisk (*****) to define all facilities or priorities (depending on where you place the asterisk, before or after the dot). Specifying the keyword **none** serves for facilities with no given priorities.

To define multiple facilities and priorities, simply separate them with a comma (**,**). To define multiple filters on one line, separate them with a semi-colon (**;**).

The following are a few examples of simple facility/priority-based filters:

```
kern.*    # Selects all kernel syslog messages with any priority
```

```
mail.crit    # Selects all mail syslog messages with priority crit and higher.
```

```
cron.!info,!debug    # Selects all cron syslog messages except those with the info
 or debug priority.
```

Property-based filters

Property-based filters let you filter syslog messages by any property, such as *timegenerated* or *syslogtag*. For more information on properties, refer to *Section 18.1.3.3.2, "Properties"*. Each

of the properties specified in the filters lets you compare it to a specific value using one of the compare-operations listed in *Table 18.1, "Property-based compare-operations"*.

Table 18.1. Property-based compare-operations

Compare-operation	Description
contains	Checks whether the provided string matches any part of the text provided by the property.
isequal	Compares the provided string against all of the text provided by the property.
startswith	Checks whether the provided string matches a prefix of the text provided by the property.
regex	Compares the provided POSIX BRE (Basic Regular Expression) regular expression against the text provided by the property.
ereregex	Compares the provided POSIX ERE (Extended Regular Expression) regular expression against the text provided by the property.

To define a property-based filter, use the following syntax:

```
:<PROPERTY>, [!]<COMPARE_OPERATION>, "<STRING>"
```

where:

- The <*PROPERTY*> attribute specifies the desired property (for example, *timegenerated*, *hostname*, etc.).
- The optional exclamation point (**!**) negates the output of the compare-operation (if prefixing the compare-operation).
- The <*COMPARE_OPERATION*> attribute specifies one of the compare-operations listed in *Table 18.1, "Property-based compare-operations"*.
- The <*STRING*> attribute specifies the value that the text provided by the property is compared to. To escape certain character (for example a quotation mark (**"**)), use the backslash character (\).

The following are few examples of property-based filters:

- The following filter selects syslog messages which contain the string **error** in their message text:

```
:msg, contains, "error"
```

- The following filter selects syslog messages received from the hostname **host1**:

```
:hostname, isequal, "host1"
```

- The following filter selects syslog messages which do not contain any mention of the words **fatal** and **error** with any or no text between them (for example, **fatal lib error**):

```
:msg, !regex, "fatal .* error"
```

Expression-based filters

Expression-based filters select syslog messages according to defined arithmetic, boolean or string operations. Expression-based filters use **rsyslog**'s own scripting language. The syntax of this language is defined in **/usr/share/doc/rsyslog-<*version-number*>/rscript_abnf.html** along with examples of various expression-based filters.

To define an expression-based filter, use the following syntax:

```
if <EXPRESSION> then <ACTION>
```

where:

- The <*EXPRESSION*> attribute represents an expression to be evaluated, for example: **$msg startswith 'DEVNAME'** or **$syslogfacility-text == 'local0'**.
- The <*ACTION*> attribute represents an action to be performed if the expression returns the value **true**.



Define an expression-based filter on a single line

When defining an expression-based filter, it must be defined on a single line.



Do not use regular expressions

Regular expressions are currently not supported in expression-based filters.

BSD-style blocks

rsyslog supports BSD-style blocks inside the **/etc/rsyslog.conf** configuration file. Each block consists of rules which are preceded with a program or hostname label. Use the '!<*PROGRAM*>' or '-<*PROGRAM*>' labels to include or exclude programs, respectively. Use the '+<*HOSTNAME*> ' or '-<*HOSTNAME*> ' labels include or exclude hostnames, respectively.

Example 18.1, "BSD-style block" shows a BSD-style block that saves all messages generated by **yum** to a file.

Example 18.1. BSD-style block

```
!yum
*.*      /var/log/named.log
```

18.1.3.2. Actions

Actions specify what is to be done with the messages filtered out by an already-defined selector. The following are some of the actions you can define in your rule:

Saving syslog messages to log files

The majority of actions specify to which log file a syslog message is saved. This is done by specifying a file path after your already-defined selector. The following is a rule comprised of a selector that selects all **cron** syslog messages and an action that saves them into the **/var/log/cron.log** log file:

```
cron.* /var/log/cron.log
```

Use a dash mark (**-**) as a prefix of the file path you specified if you want to omit syncing the desired log file after every syslog message is generated.

Your specified file path can be either static or dynamic. Static files are represented by a simple file path as was shown in the example above. Dynamic files are represented by a template and a question mark (**?**) prefix. For more information on templates, refer to *Section 18.1.3.3.1, "Generating dynamic file names"*.

If the file you specified is an existing **tty** or **/dev/console** device, syslog messages are sent to standard output (using special **tty**-handling) or your console (using special **/dev/console**-handling) when using the X Window System, respectively.

Sending syslog messages over the network

rsyslog allows you to send and receive syslog messages over the network. This feature allows to administer syslog messages of multiple hosts on one machine. To forward syslog messages to a remote machine, use the following syntax:

```
@[(<OPTION>)]<HOST>:[<PORT>]
```

where:

- The at sign (@) indicates that the syslog messages are forwarded to a host using the UDP protocol. To use the TCP protocol, use two at signs with no space between them (@@).
- The <*OPTION*> attribute can be replaced with an option such as **z<*NUMBER*>** . This option enables **zlib** compression for syslog messages; the <*NUMBER*> attribute specifies the level of compression. To define multiple options, simply separate each one of them with a comma (**,**).
- The <*HOST*> attribute specifies the host which receives the selected syslog messages.
- The <*PORT*> attribute specifies the host machine's port.

When specifying an IPv6 address as the host, enclose the address in square brackets (**[**, **]**).

The following are some examples of actions that forward syslog messages over the network (note that all actions are preceded with a selector that selects all messages with any priority):

```
*.* @192.168.0.1    # Forwards messages to 192.168.0.1 via the UDP protocol
```

```
*.* @@example.com:18    # Forwards messages to "example.com" using port 18 and the TCP
 protocol
```

```
*.* @(z9)[2001::1]    # Compresses messages with zlib (level 9 compression)
                      # and forwards them to 2001::1 using the UDP protocol
```

Output channels

Output channels are primarily used for log file rotation (for more info on log file rotation, refer to *Section 18.2.1, "Configuring logrotate"*), that is, to specify the maximum size a log file can grow to. To define an output channel, use the following syntax:

```
$outchannel <NAME>, <FILE_NAME>, <MAX_SIZE>, <ACTION>
```

where:

- The *<NAME>* attribute specifies the name of the output channel.
- The *<FILE_NAME>* attribute specifies the name of the output file.
- The *<MAX_SIZE>* attribute represents the maximum size the specified file (in *<FILE_NAME>*) can grow to. This value is specified in *bytes*.
- The *<ACTION>* attribute specifies the action that is taken when the maximum size, defined in *<MAX_SIZE>*, is hit.

Example 18.2, "Output channel log rotation" shows a simple log rotation through the use of an output channel. First, the output channel is defined via the *$outchannel* directive and then used in a rule which selects every syslog message with any priority and executes the previously-defined output channel on the acquired syslog messages. Once the limit (in the example `100 MB`) is hit, the **`/home/joe/log_rotation_script`** is executed. This script can contain anything from moving the file into a different folder, editing specific content out of it, or simply removing it.

Example 18.2. Output channel log rotation

```
$outchannel log_rotation,/var/log/test_log.log, 104857600, /home/joe/
log_rotation_script

*.* $log_rotation
```



Support for output channels is to be removed in the future

Output channels are currently supported by **rsyslog**, however, they are planned to be removed in the nearby future.

Sending syslog messages to specific users

rsyslog can send syslog messages to specific users by simply specifying a username of the user you wish to send the messages to. To specify more than one user, separate each username with a comma (**,**). To send messages to every user that is currently logged on, use an asterisk (*****).

Executing a program

rsyslog lets you execute a program for selected syslog messages and uses the `system()` call to execute the program in shell. To specify a program to be executed, prefix it with a caret character (**^**). Consequently, specify a template that formats the received message and passes it to the specified executable as a one line parameter (for more information on templates, refer to *Section 18.1.3.3, "Templates"*). In the following example, any syslog message with any priority is

selected, formatted with the *template* template and passed as a parameter to the **test-program** program, which is then executed with the provided parameter:

```
*.* ^test-program;template
```



Be careful when using the shell execute action

When accepting messages from any host, and using the shell execute action, you may be vulnerable to command injection. An attacker may try to inject and execute commands specified by the attacker in the program you specified (in your action) to be executed. To avoid any possible security threats, thoroughly consider the use of the shell execute action.

Inputting syslog messages in a database

Selected syslog messages can be directly written into a database table using the *database writer* action. The database writer uses the following syntax:

```
:<PLUGIN>:<DB_HOST>,<DB_NAME>,<DB_USER>,<DB_PASSWORD>;[<TEMPLATE>]
```

where:

- The <*PLUGIN*> calls the specified plug-in that handles the database writing (for example, the `ommysql` plug-in).
- The <*DB_HOST*> attribute specifies the database hostname.
- The <*DB_NAME*> attribute specifies the name of the database.
- The <*DB_USER*> attribute specifies the database user.
- The <*DB_PASSWORD*> attribute specifies the password used with the aforementioned database user.
- The <*TEMPLATE*> attribute specifies an optional use of a template that modifies the syslog message. For more information on templates, refer to *Section 18.1.3.3, “Templates”*.



Using MySQL and PostgreSQL

Currently, **rsyslog** provides support for `MySQL` (for more information, refer to **`/usr/share/doc/rsyslog-<version-number>/rsyslog_mysql.html`**) and `PostgreSQL` databases only. In order to use the `MySQL` and `PostgreSQL` database writer functionality, install the *rsyslog-mysql* and *rsyslog-pgsql* packages installed, respectively. Also, make sure you load the appropriate modules in your **`/etc/rsyslog.conf`** configuration file:

```
$ModLoad ommysql    # Output module for MySQL support
$ModLoad ompgsql    # Output module for PostgreSQL support
```

For more information on **rsyslog** modules, refer to *Section 18.1.2, "Modules"*.

Alternatively, you may use a generic database interface provided by the `omlibdb` module. However, this module is currently not compiled.

Discarding syslog messages

To discard your selected messages, use the tilde character (**~**). The following rule discards any cron syslog messages:

```
cron.* ~
```

For each selector, you are allowed to specify multiple actions. To specify multiple actions for one selector, write each action on a separate line and precede it with an ampersand character (&). Only the first action is allowed to have a selector specified on its line. The following is an example of a rule with multiple actions:

```
kern.=crit joe
& ^test-program;temp
& @192.168.0.1
```

In the example above, all kernel syslog messages with the critical priority (*`crit`*) are send to user `joe`, processed by the template *`temp`* and passed on to the *`test-program`* executable, and forwarded to `192.168.0.1` via the `UDP` protocol.

Specifying multiple actions improves the overall performance of the desired outcome since the specified selector has to be evaluated only once.

Note that any action can be followed by a template that formats the message. To specify a template, suffix an action with a semicolon (**`;`**) and specify the name of the template.



Using templates

A template must be defined before it is used in an action, otherwise, it is ignored.

For more information on templates, refer to *Section 18.1.3.3, "Templates"*.

18.1.3.3. Templates

Any output that is generated by **rsyslog** can be modified and formatted according to your needs through the use of templates. To create a template use the following syntax:

```
$template <TEMPLATE_NAME>,"text %<PROPERTY>% more text", [<OPTION>]
```

where:

- *`$template`* is the template directive that indicates that the text following it, defines a template.
- *<TEMPLATE_NAME>* is the name of the template. Use this name to refer to the template.
- Anything between the two quotation marks (**"**…**"**) is the actual template text. Within this text, you are allowed to escape characters in order to use their functionality, such as **\n** for new line or **\r** for carriage return. Other characters, such as **%** or **"**, have to be escaped in case you want to those characters literally.

  The text specified within two percent signs (**%**) specifies a *property* that is consequently replaced with the property's actual value. For more information on properties, refer to *Section 18.1.3.3.2, "Properties"*
- The *<OPTION>* attribute specifies any options that modify the template functionality. Do not mistake these for property options, which are defined inside the template text (between **"**…**"**). The currently supported template options are *`sql`* and *`stdsql`* used for formatting the text as an SQL query.



The sql and stdsql options

Note that the database writer (for more information, refer to section *Inputting syslog messages in a database* in *Section 18.1.3.2, "Actions"*) checks whether the *`sql`* and *`stdsql`* options are specified in the template. If they are not, the database writer does not perform any action. This is to prevent any possible security threats, such as SQL injection.

18.1.3.3.1. Generating dynamic file names

Templates can be used to generate dynamic file names. By specifying a property as a part of the file path, a new file will be created for each unique property. For example, use the *`timegenerated`* property to generate a unique file name for each syslog message:

```
$template DynamicFile,"/var/log/test_logs/%timegenerated%-test.log"
```

Keep in mind that the *`$template`* directive only specifies the template. You must use it inside a rule for it to take effect:

```
*.* ?DynamicFile
```

18.1.3.3.2. Properties

Properties defined inside a template (within two percent signs (**%**)) allow you to access various contents of a syslog message through the use of a *property replacer*. To define a property inside a template (between the two quotation marks (**"**…**"**)), use the following syntax:

```
%<PROPERTY_NAME>[:<FROM_CHAR>:<TO_CHAR>:<OPTION>]%
```

where:

- The *<PROPERTY_NAME>* attribute specifies the name of a property. A comprehensible list of all available properties and their detailed description can be found in **/usr/share/doc/rsyslog-<*version-number*>/property_replacer.html** under the section *Available Properties*.
- *<FROM_CHAR>* and *<TO_CHAR>* attributes denote a range of characters that the specified property will act upon. Alternatively, regular expressions can be used to specify a range of characters. To do so, specify the letter **R** as the *<FROM_CHAR>* attribute and specify your desired regular expression as the *<TO_CHAR>* attribute.
- The *<OPTION>* attribute specifies any property options. A comprehensible list of all available properties and their detailed description can be found in **/usr/share/doc/rsyslog-<*version-number*>/property_replacer.html** under the section *Property Options*.

The following are some examples of simple properties:

- The following property simply obtains the whole message text of a syslog message:

```
%msg%
```

- The following property obtains the first two characters of the message text of a syslog message:

```
%msg:1:2%
```

- The following property obtains the whole message text of a syslog message and drops its last line feed character:

```
%msg:::drop-last-lf%
```

- The following property obtains the first 10 characters of the timestamp that is generated when the syslog message is received and formats it according to the RFC 3999 date standard.

```
%timegenerated:1:10:date-rfc3339%
```

18.1.3.3.3. Template Examples

This section presents few examples of **rsyslog** templates.

Example 18.3, "A verbose syslog message template" shows a template that formats a syslog message so that it outputs the message's severity, facility, the timestamp of when the message was received, the hostname, the message tag, the message text, and ends with a new line.

Example 18.3. A verbose syslog message template

```
$template verbose,"%syslogseverity%,%syslogfacility%,%timegenerated%,%HOSTNAME%,%syslogtag%,%msg%\n"
```

Example 18.4, "A wall message template" shows a template that resembles a traditional wall message (a message that is send to every user that is logged in and has their *mesg(1)* permission set to *yes*).

This template outputs the message text, along with a hostname, message tag and a timestamp, on a new line (using **\r** and **\n**) and rings the bell (using **\7**).

Example 18.4. A wall message template

```
$template wallmsg,"\r\n\7Message from syslogd@%HOSTNAME% at %timegenerated% ...\r\n
 %syslogtag% %msg%\n\r"
```

Example 18.5, "A database formatted message template" shows a template that formats a syslog message so that it can be used as a database query. Notice the use of the *sql* option at the end of the template specified as the template option. It tells the database writer to format the message as an MySQL SQL query.

Example 18.5. A database formatted message template

```
$template dbFormat,"insert into SystemEvents (Message, Facility,FromHost, Priority,
 DeviceReportedTime, ReceivedAt, InfoUnitID, SysLogTag) values ('%msg%', %syslogfacility
%, '%HOSTNAME%',%syslogpriority%, '%timereported:::date-mysql%', '%timegenerated:::date-
mysql%', %iut%, '%syslogtag%')",sql
```

rsyslog also contains a set of predefined templates identified by the **RSYSLOG_** prefix. It is advisable to not create a template using this prefix to avoid any conflicts. The following list shows these predefined templates along with their definitions.

RSYSLOG_DebugFormat

```
"Debug line with all properties:\nFROMHOST: '%FROMHOST%', fromhost-ip: '%fromhost-ip%',
 HOSTNAME: '%HOSTNAME%', PRI: %PRI%,\nsyslogtag '%syslogtag%', programname: '%programname
%', APP-NAME: '%APP-NAME%', PROCID: '%PROCID%', MSGID: '%MSGID%',\nTIMESTAMP: '%TIMESTAMP
%', STRUCTURED-DATA: '%STRUCTURED-DATA%',\nmsg: '%msg%'\nescaped msg: '%msg:::drop-cc
%'\nrawmsg: '%rawmsg%'\n\n\"
```

RSYSLOG_SyslogProtocol23Format

```
"<%PRI%>1 %TIMESTAMP:::date-rfc3339% %HOSTNAME% %APP-NAME% %PROCID% %MSGID% %STRUCTURED-
DATA% %msg%\n\"
```

RSYSLOG_FileFormat

```
"%TIMESTAMP:::date-rfc3339% %HOSTNAME% %syslogtag%%msg:::sp-if-no-1st-sp%%msg:::drop-
last-lf%\n\"
```

RSYSLOG_TraditionalFileFormat

```
"%TIMESTAMP% %HOSTNAME% %syslogtag%%msg:::sp-if-no-1st-sp%%msg:::drop-last-lf%\n\"
```

RSYSLOG_ForwardFormat

```
"<%PRI%>%TIMESTAMP:::date-rfc3339% %HOSTNAME% %syslogtag:1:32%%msg:::sp-if-no-1st-sp%%msg
%\"
```

RSYSLOG_TraditionalForwardFormat

```
"<%PRI%>%TIMESTAMP% %HOSTNAME% %syslogtag:1:32%%msg:::sp-if-no-1st-sp%%msg%\"
```

18.1.4. rsyslog Command Line Configuration

Some of **rsyslog**'s functionality can be configured through the command line options, as **sysklogd**'s can. Note that as of version 3 of **rsyslog**, this method was deprecated. To enable some of these option, you must specify the compatibility mode **rsyslog** should run in. However, configuring **rsyslog** through the command line options should be avoided.

To specify the compatibility mode **rsyslog** should run in, use the **-c** option. When no parameter is specified, **rsyslog** tries to be compatible with **sysklogd**. This is partially achieved by activating configuration directives that modify your configuration accordingly. Therefore, it is advisable to supply this option with a number that matches the major version of **rsyslog** that is in use and update your **/etc/rsyslog.conf** configuration file accordingly. If you want to, for example, use **sysklogd** options (which were deprecated in version 3 of **rsyslog**), you can specify so by executing the following command:

```
~]# rsyslogd -c 2
```

Options that are passed to the `rsyslogd` daemon, including the backward compatibility mode, can be specified in the **/etc/sysconfig/rsyslog** configuration file.

For more information on various **rsyslogd** options, refer to **man rsyslogd**.

18.2. Locating Log Files

Most log files are located in the **/var/log/** directory. Some applications such as **httpd** and **samba** have a directory within **/var/log/** for their log files.

You may notice multiple files in the **/var/log/** directory with numbers after them (for example, **cron-20100906**). These numbers represent a timestamp that has been added to a rotated log file. Log files are rotated so their file sizes do not become too large. The **logrotate** package contains a cron task that automatically rotates log files according to the **/etc/logrotate.conf** configuration file and the configuration files in the **/etc/logrotate.d/** directory.

18.2.1. Configuring logrotate

The following is a sample **/etc/logrotate.conf** configuration file:

```
# rotate log files weekly
weekly
# keep 4 weeks worth of backlogs
rotate 4
# uncomment this if you want your log files compressed
compress
```

All of the lines in the sample configuration file define global options that apply to every log file. In our example, log files are rotated weekly, rotated log files are kept for the duration of 4 weeks, and all

rotated log files are compressed by **gzip** into the **.gz** format. Any lines that begin with a hash sign (#) are comments and are not processed

You may define configuration options for a specific log file and place it under the global options. However, it is advisable to create a separate configuration file for any specific log file in the **/etc/logrotate.d/** directory and define any configuration options there.

The following is an example of a configuration file placed in the **/etc/logrotate.d/** directory:

```
/var/log/messages {
    rotate 5
    weekly
    postrotate
    /usr/bin/killall -HUP syslogd
    endscript
}
```

The configuration options in this file are specific for the **/var/log/messages** log file only. The settings specified here override the global settings where possible. Thus the rotated **/var/log/messages** log file will be kept for five weeks instead of four weeks as was defined in the global options.

The following is a list of some of the directives you can specify in your **logrotate** configuration file:

- *weekly* — Specifies the rotation of log files on a weekly basis. Similar directives include:
  - *daily*
  - *monthly*
  - *yearly*
- *compress* — Enables compression of rotated log files. Similar directives include:
  - *nocompress*
  - *compresscmd* — Specifies the command to be used for compressing.
  - *uncompresscmd*
  - *compressext* — Specifies what extension is to be used for compressing.
  - *compressoptions* — Lets you specify any options that may be passed to the used compression program.
  - *delaycompress* — Postpones the compression of log files to the next rotation of log files.
- *rotate <INTEGER>* — Specifies the number of rotations a log file undergoes before it is removed or mailed to a specific address. If the value `0` is specified, old log files are removed instead of rotated.
- *mail <ADDRESS>* — This option enables mailing of log files that have been rotated as many times as is defined by the *rotate* directive to the specified address. Similar directives include:
  - *nomail*
  - *mailfirst* — Specifies that the just-rotated log files are to be mailed, instead of the about-to-expire log files.

- *maillast* — Specifies that the just-rotated log files are to be mailed, instead of the about-to-expire log files. This is the default option when *mail* is enabled.

For the full list of directives and various configuration options, refer to the **logrotate** man page (**man logrotate**).

18.3. Viewing Log Files

Most log files are in plain text format. You can view them with any text editor such as **Vi** or **Emacs**. Some log files are readable by all users on the system; however, root privileges are required to read most log files.

To view system log files in an interactive, real-time application, use the **Log File Viewer**.



Installing the gnome-system-log package

In order to use the **Log File Viewer**, first ensure the *gnome-system-log* package is installed on your system by running, as root:

```
yum install gnome-system-log
```

For more information on installing packages with Yum, refer to *Section 4.2.4, "Installing Packages"*.

After you have installed the *gnome-system-log* package, you can open the **Log File Viewer** by selecting **Applications** **System Tools** **Log File Viewer** from the **Activities** menu, or type the following command at a shell prompt:

```
gnome-system-log
```

The application only displays log files that exist; thus, the list might differ from the one shown in *Figure 18.1, " Log File Viewer "*.

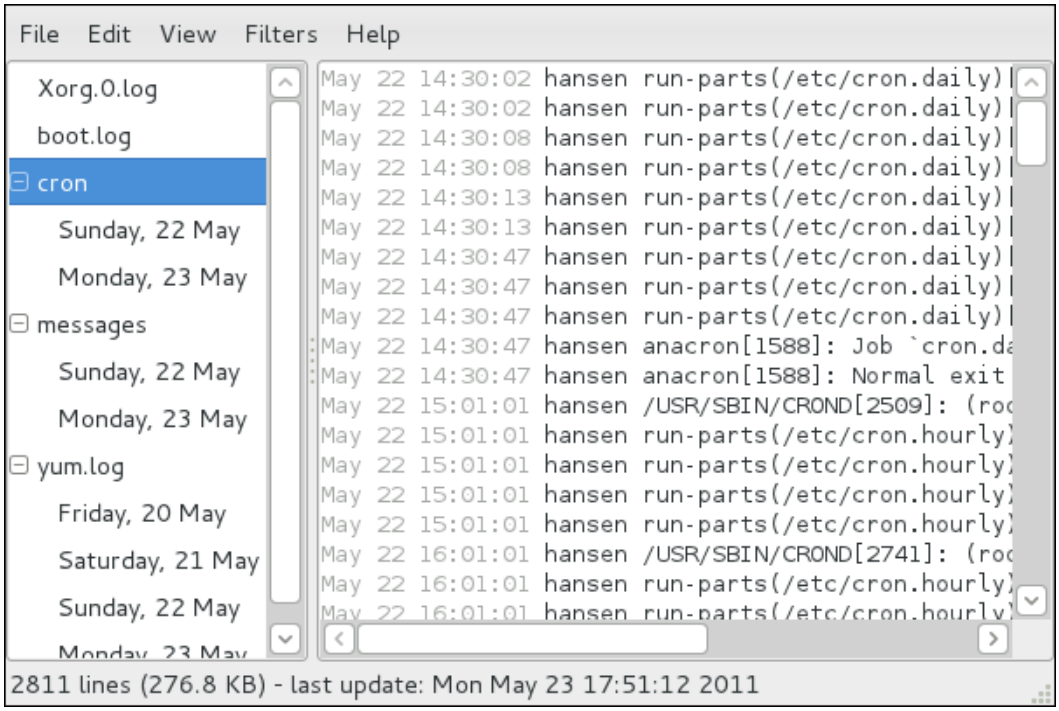


Figure 18.1. Log File Viewer

The **Log File Viewer** application lets you filter any existing log file. Click on **Filters** from the menu and select **Manage Filters** to define or edit your desired filter.

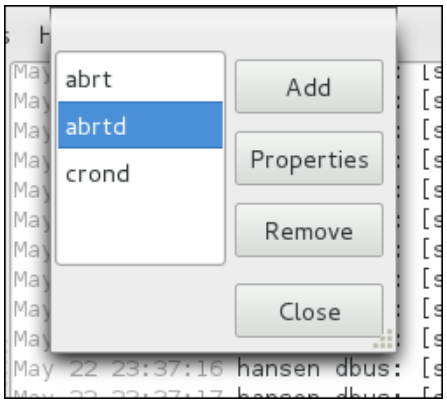


Figure 18.2. Log File Viewer — filters

Adding or editing a filter lets you define its parameters as is shown in *Figure 18.3, " Log File Viewer — defining a filter "*.

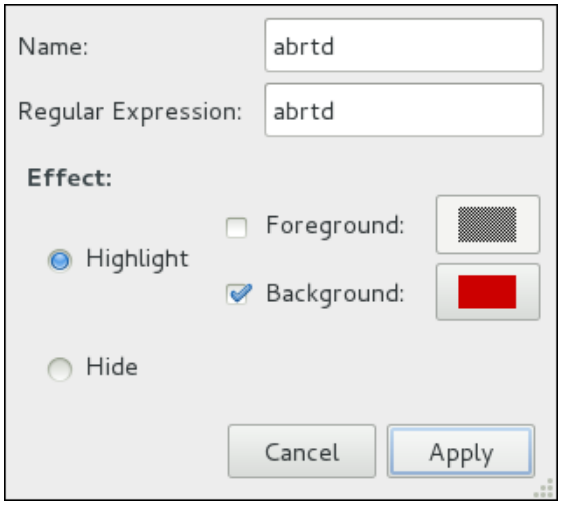


Figure 18.3. Log File Viewer — defining a filter

When defining a filter, you can edit the following parameters:

- **Name** — Specifies the name of the filter.
- **Regular Expression** — Specifies the regular expression that will be applied to the log file and will attempt to match any possible strings of text in it.
- **Effect**
  - **Highlight** — If checked, the found results will be highlighted with the selected color. You may select whether to highlight the background or the foreground of the text.
  - **Hide** — If checked, the found results will be hidden from the log file you are viewing.

When you have at least one filter defined, you may select it from the **Filters** menu and it will automatically search for the strings you have defined in the filter and highlight/hide every successful match in the log file you are currently viewing.

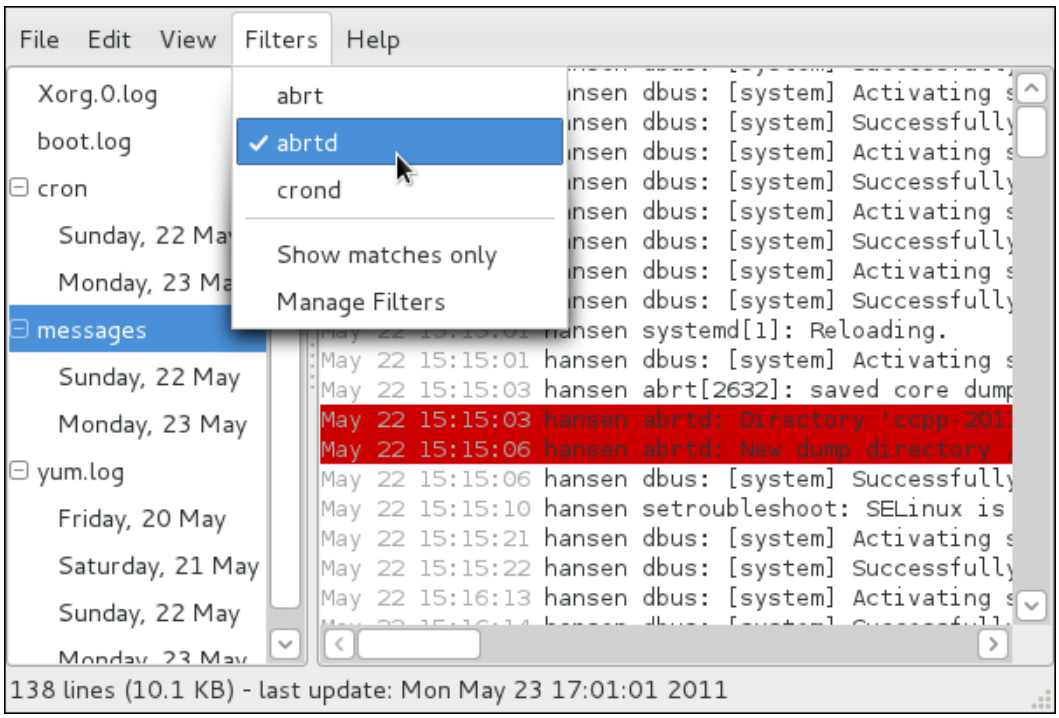


Figure 18.4. Log File Viewer — enabling a filter

When you check the **Show matches only** option, only the matched strings will be shown in the log file you are currently viewing.

18.4. Adding a Log File

To add a log file you wish to view in the list, select **File□□□ Open**. This will display the **Open Log** window where you can select the directory and file name of the log file you wish to view.*Figure 18.5, "Log File Viewer — adding a log file"* illustrates the **Open Log** window.

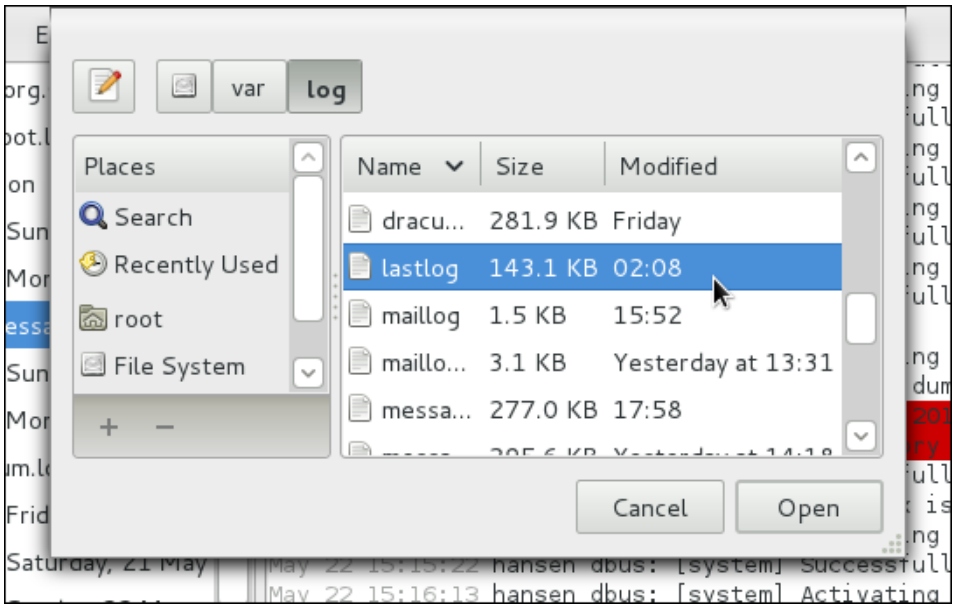


Figure 18.5. Log File Viewer — adding a log file

Click on the **Open** button to open the file. The file is immediately added to the viewing list where you can select it and view its contents.

Reading zipped log files

The **Log File Viewer** also allows you to open log files zipped in the **.gz** format.

18.5. Monitoring Log Files

Log File Viewer monitors all opened logs by default. If a new line is added to a monitored log file, the log name appears in bold in the log list. If the log file is selected or displayed, the new lines appear in bold at the bottom of the log file. *Figure 18.6, "Log File Viewer — new log alert"* illustrates a new alert in the **yum.log** log file and in the **messages** log file. Clicking on the **messages** log file displays the logs in the file with the new lines in bold.

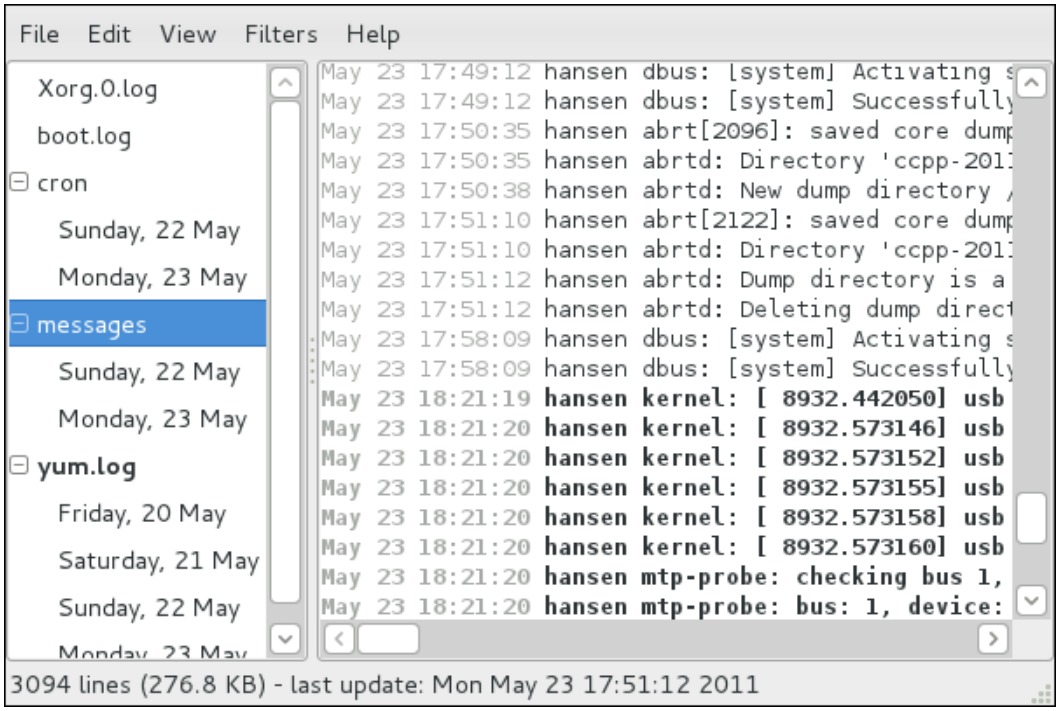


Figure 18.6. Log File Viewer — new log alert

18.6. Additional Resources

To learn more about **rsyslog**, **logrotate**, and log files in general, refer to the following resources.

18.6.1. Installed Documentation

- **`rsyslogd`** manual page — Type **`man rsyslogd`** to learn more about **`rsyslogd`** and its many options.
- **`rsyslog.conf`** manual page — Type **`man rsyslog.conf`** to learn more about the **`/etc/rsyslog.conf`** configuration file and its many options.
- **`/usr/share/doc/rsyslog-<version-number>/`** — After installing the *rsyslog* package, this directory contains extensive documentation in the `html` format.
- **`logrotate`** manual page — Type **`man logrotate`** to learn more about **`logrotate`** and its many options.

18.6.2. Useful Websites

- *http://www.rsyslog.com/* — Offers a thorough technical breakdown of *rsyslog* features, documentation, configuration examples, and video tutorials.
- *http://wiki.rsyslog.com/index.php/Main_Page* — Contains useful **`/etc/rsyslog.conf`** configuration examples.

Automating System Tasks

In Linux, tasks, which are also known as *jobs*, can be configured to run automatically within a specified period of time, on a specified date, or when the system load average is below a specified number. Fedora is pre-configured to run important system tasks to keep the system updated. For example, the slocate database used by the **locate** command is updated daily. A system administrator can use automated tasks to perform periodic backups, monitor the system, run custom scripts, and more.

Fedora comes with several automated tasks utilities: **cron**, **at**, and **batch**.

19.1. Cron and Anacron

Both, Cron and Anacron, are daemons that can be used to schedule the execution of recurring tasks according to a combination of the time, day of the month, month, day of the week, and week.

Cron assumes that the system is on continuously. If the system is not on when a job is scheduled, it is not executed. Cron allows jobs to be run as often as every minute. Anacron does not assume the system is always on, remembers every scheduled job, and executes it the next time the system is up. However, Anacron can only run a job once a day. To schedule recurring jobs, refer to *Section 19.1.2, "Configuring Anacron Jobs"* or *Section 19.1.3, "Configuring Cron Jobs"*. To schedule one-time jobs, refer to *Section 19.2, "At and Batch"*.

To use the cron service, the **cronie** RPM package must be installed and the **crond** service must be running. **anacron** is a sub-package of **cronie**. To determine if these packages are installed, use the **rpm -q cronie cronie-anacron** command.

19.1.1. Starting and Stopping the Service

To determine if the service is running, use the following command:

```
systemctl is-active crond.service
```

To start the cron service, type the following at a shell prompt as `root`:

```
systemctl start crond.service
```

To stop the service, run the following command as `root`:

```
systemctl stop crond.service
```

It is recommended that you start the service at boot time. To do so, use the following command as `root`:

```
systemctl enable crond.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

19.1.2. Configuring Anacron Jobs

The main configuration file to schedule jobs is **/etc/anacrontab** (only `root` is allowed to modify this file), which contains the following lines:

```
SHELL=/bin/sh
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root
# the maximal random delay added to the base delay of the jobs
RANDOM_DELAY=45
# the jobs will be started during the following hours only
START_HOURS_RANGE=3-22

#period in days   delay in minutes   job-identifier   command
1         5     cron.daily    nice run-parts /etc/cron.daily
7         25    cron.weekly   nice run-parts /etc/cron.weekly
@monthly  45    cron.monthly  nice run-parts /etc/cron.monthly
```

The first three lines are variables used to configure the environment in which the anacron tasks are run. The **SHELL** variable tells the system which shell environment to use (in this example the bash shell). The **PATH** variable defines the path used to execute commands. The output of the anacron jobs are emailed to the username defined with the **MAILTO** variable. If the **MAILTO** variable is not defined, (i.e. is empty, **MAILTO=**), email is not sent.

The next two lines are variables that modify the time for each scheduled job. The **RANDOM_DELAY** variable denotes the maximum number of minutes that will be added to the **delay in minutes** variable which is specified for each job. The minimum delay value is set, by default, to 6 minutes. A **RANDOM_DELAY** set to 12 would therefore add, randomly, between 6 and 12 minutes to the **delay in minutes** for each job in that particular anacrontab. **RANDOM_DELAY** can also be set to a value below 6, or even 0. When set to 0, no random delay is added. This proves to be useful when, for example, more computers that share one network connection need to download the same data every day. The **START_HOURS_RANGE** variable defines an interval (in hours) when scheduled jobs can be run. In case this time interval is missed, for example, due to a power down, then scheduled jobs are not executed that day.

The rest of the lines in the **/etc/anacrontab** file represent scheduled jobs and have the following format:

```
period in days   delay in minutes   job-identifier   command
```

- **period in days** — specifies the frequency of execution of a job in days. This variable can be represented by an integer or a macro (**@daily**, **@weekly**, **@monthly**), where **@daily** denotes the same value as the integer 1, **@weekly** the same as 7, and **@monthly** specifies that the job is run once a month, independent on the length of the month.
- **delay in minutes** — specifies the number of minutes anacron waits, if necessary, before executing a job. This variable is represented by an integer where 0 means no delay.
- **job-identifier** — specifies a unique name of a job which is used in the log files.
- **command** — specifies the command to execute. The command can either be a command such as **ls /proc >> /tmp/proc** or a command to execute a custom script.

Any lines that begin with a hash sign (#) are comments and are not processed.

19.1.2.1. Examples of Anacron Jobs

The following example shows a simple **/etc/anacrontab** file:

```
SHELL=/bin/sh
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root
```

```
# the maximal random delay added to the base delay of the jobs
RANDOM_DELAY=30
# the jobs will be started during the following hours only
START_HOURS_RANGE=16-20

#period in days   delay in minutes   job-identifier   command
1         20    dailyjob      nice run-parts /etc/cron.daily
7         25    weeklyjob     /etc/weeklyjob.bash
@monthly  45    monthlyjob    ls /proc >> /tmp/proc
```

All jobs defined in this **anacrontab** file are randomly delayed by 6-30 minutes and can be executed between 16:00 and 20:00. Thus, the first defined job will run anywhere between 16:26 and 16:50 every day. The command specified for this job will execute all present programs in the **/etc/cron.daily** directory (using the **run-parts** script which takes a directory as a command-line argument and sequentially executes every program within that directory). The second specified job will be executed once a week and will execute the **weeklyjob.bash** script in the **/etc** directory. The third job is executed once a month and runs a command to write the contents of the **/proc** to the **/tmp/proc** file (e.g. **ls /proc >> /tmp/proc**).

19.1.2.1.1. Disabling Anacron

In case your system is continuously on and you do not require anacron to run your scheduled jobs, you may uninstall the **cronie-anacron** package. Thus, you will be able to define jobs using crontabs only.

19.1.3. Configuring Cron Jobs

The configuration file to configure cron jobs, **/etc/crontab** (only `root` is allowed to modify this file), contains the following lines:

```
SHELL=/bin/bash
PATH=/sbin:/bin:/usr/sbin:/usr/bin
MAILTO=root
HOME=/
# For details see man 4 crontabs
# Example of job definition:
# .---------------- minute (0 - 59)
# | .------------- hour (0 - 23)
# | | .---------- day of month (1 - 31)
# | | | .------- month (1 - 12) OR jan,feb,mar,apr ...
# | | | | .---- day of week (0 - 6) (Sunday=0 or 7) OR sun,mon,tue,wed,thu,fri,sat
# | | | | |
# * * * * * user command to be executed
```

The first three lines contain the same variables as an **anacrontab** file, **SHELL**, **PATH** and **MAILTO**. For more information about these variables, refer to *Section 19.1.2, "Configuring Anacron Jobs"*. The fourth line contains the **HOME** variable. The **HOME** variable can be used to set the home directory to use when executing commands or scripts.

The rest of the lines in the **/etc/crontab** file represent scheduled jobs and have the following format:

```
minute   hour   day   month   day of week   user   command
```

- **minute** — any integer from 0 to 59
- **hour** — any integer from 0 to 23

- **day** — any integer from 1 to 31 (must be a valid day if a month is specified)
- **month** — any integer from 1 to 12 (or the short name of the month such as jan or feb)
- **day of week** — any integer from 0 to 7, where 0 or 7 represents Sunday (or the short name of the week such as sun or mon)
- **user** — specifies the user under which the jobs are run
- **command** — the command to execute (the command can either be a command such as **ls /proc >> /tmp/proc** or the command to execute a custom script)

For any of the above values, an asterisk (*) can be used to specify all valid values. For example, an asterisk for the month value means execute the command every month within the constraints of the other values.

A hyphen (-) between integers specifies a range of integers. For example, **1-4** means the integers 1, 2, 3, and 4.

A list of values separated by commas (,) specifies a list. For example, **3, 4, 6, 8** indicates those four specific integers.

The forward slash (/) can be used to specify step values. The value of an integer can be skipped within a range by following the range with ***/integer***. For example, **0-59/2** can be used to define every other minute in the minute field. Step values can also be used with an asterisk. For instance, the value ***/3** can be used in the month field to run the task every third month.

Any lines that begin with a hash sign (#) are comments and are not processed.

Users other than `root` can configure cron tasks by using the **crontab** utility. All user-defined crontabs are stored in the **/var/spool/cron/** directory and are executed using the usernames of the users that created them. To create a crontab as a user, login as that user and type the command **crontab -e** to edit the user's crontab using the editor specified by the **VISUAL** or **EDITOR** environment variable. The file uses the same format as **/etc/crontab**. When the changes to the crontab are saved, the crontab is stored according to username and written to the file **/var/spool/cron/*username*** . To list the contents of your own personal crontab file, use the **crontab -l** command.



Do not specify a user

When using the **crontab** utility, there is no need to specify a user when defining a job.

The **/etc/cron.d/** directory contains files that have the same syntax as the **/etc/crontab** file. Only `root` is allowed to create and modify files in this directory.



Do not restart the daemon to apply the changes

The cron daemon checks the **/etc/anacrontab** file, the **/etc/crontab** file, the **/etc/cron.d/** directory, and the **/var/spool/cron/** directory every minute for any changes. If any changes are found, they are loaded into memory. Thus, the daemon does not need to be restarted if an anacrontab or a crontab file is changed.

19.1.4. Controlling Access to Cron

The **/etc/cron.allow** and **/etc/cron.deny** files are used to restrict access to cron. The format of both access control files is one username on each line. Whitespace is not permitted in either file. The cron daemon (**crond**) does not have to be restarted if the access control files are modified. The access control files are checked each time a user tries to add or delete a cron job.

The `root` user can always use cron, regardless of the usernames listed in the access control files.

If the file **cron.allow** exists, only users listed in it are allowed to use cron, and the **cron.deny** file is ignored.

If **cron.allow** does not exist, users listed in **cron.deny** are not allowed to use cron.

Access can also be controlled through Pluggable Authentication Modules (PAM). These settings are stored in **/etc/security/access.conf**. For example, adding the following line in this file forbids creating crontabs for all users except the `root` user:

```
-:ALL EXCEPT root :cron
```

The forbidden jobs are logged in an appropriate log file or, when using “crontab -e”, returned to the standard output. For more information, refer to **access.conf.5** (i.e. **man 5 access.conf**).

19.1.5. Black/White Listing of Cron Jobs

Black/White listing of jobs is used to omit parts of the defined jobs that do not need to be executed. When calling the **run-parts** script on a cron folder, such as **/etc/cron.daily**, we can define which of the programs in this folder will not be executed by **run-parts**.

To define a black list, create a **jobs.deny** file in the folder that **run-parts** will be executing from. For example, if we need to omit a particular program from /etc/cron.daily, then, a file **/etc/cron.daily/jobs.deny** has to be created. In this file, specify the names of the omitted programs from the same directory. These will not be executed when a command, such as **run-parts /etc/cron.daily**, is executed by a specific job.

To define a white list, create a **jobs.allow** file.

The principles of **jobs.deny** and **jobs.allow** are the same as those of **cron.deny** and **cron.allow** described in section *Section 19.1.4, “Controlling Access to Cron”*.

19.2. At and Batch

While cron is used to schedule recurring tasks, the **at** command is used to schedule a one-time task at a specific time and the **batch** command is used to schedule a one-time task to be executed when the systems load average drops below 0.8.

To use **at** or **batch**, the **at** RPM package must be installed, and the **atd** service must be running. To determine if the package is installed, use the **rpm -q at** command. To determine if the service is running, use the following command:

```
systemctl is-active atd.service
```

19.2.1. Configuring At Jobs

To schedule a one-time job at a specific time, type the command **at *time*** , where ***time*** is the time to execute the command.

The argument *time* can be one of the following:

- HH:MM format — For example, 04:00 specifies 4:00 a.m. If the time is already past, it is executed at the specified time the next day.
- midnight — Specifies 12:00 a.m.
- noon — Specifies 12:00 p.m.
- teatime — Specifies 4:00 p.m.
- month-name day year format — For example, January 15 2002 specifies the 15th day of January in the year 2002. The year is optional.
- MMDDYY, MM/DD/YY, or MM.DD.YY formats — For example, 011502 for the 15th day of January in the year 2002.
- now + time — time is in minutes, hours, days, or weeks. For example, now + 5 days specifies that the command should be executed at the same time five days from now.

The time must be specified first, followed by the optional date. For more information about the time format, read the **/usr/share/doc/at-*version*/timespec** text file.

After typing the **at** command with the time argument, the `at>` prompt is displayed. Type the command to execute, press **Enter**, and press **Ctrl**+**D** . Multiple commands can be specified by typing each command followed by the **Enter** key. After typing all the commands, press **Enter** to go to a blank line and press **Ctrl**+**D** . Alternatively, a shell script can be entered at the prompt, pressing **Enter** after each line in the script, and pressing **Ctrl**+**D** on a blank line to exit. If a script is entered, the shell used is the shell set in the user's `SHELL` environment, the user's login shell, or **/bin/sh** (whichever is found first).

If the set of commands or script tries to display information to standard output, the output is emailed to the user.

Use the command **atq** to view pending jobs. Refer to *Section 19.2.3, "Viewing Pending Jobs"* for more information.

Usage of the **at** command can be restricted. For more information, refer to *Section 19.2.5, "Controlling Access to At and Batch"* for details.

19.2.2. Configuring Batch Jobs

To execute a one-time task when the load average is below 0.8, use the **batch** command.

After typing the **batch** command, the `at>` prompt is displayed. Type the command to execute, press **Enter**, and press **Ctrl**+**D** . Multiple commands can be specified by typing each command followed

by the **Enter** key. After typing all the commands, press **Enter** to go to a blank line and press **Ctrl**+**D** . Alternatively, a shell script can be entered at the prompt, pressing **Enter** after each line in the script, and pressing **Ctrl**+**D** on a blank line to exit. If a script is entered, the shell used is the shell set in the user's SHELL environment, the user's login shell, or **/bin/sh** (whichever is found first). As soon as the load average is below 0.8, the set of commands or script is executed.

If the set of commands or script tries to display information to standard out, the output is emailed to the user.

Use the command **atq** to view pending jobs. Refer to *Section 19.2.3, "Viewing Pending Jobs"* for more information.

Usage of the **batch** command can be restricted. For more information, refer to *Section 19.2.5, "Controlling Access to At and Batch"* for details.

19.2.3. Viewing Pending Jobs

To view pending **at** and **batch** jobs, use the **atq** command. The **atq** command displays a list of pending jobs, with each job on a line. Each line follows the job number, date, hour, job class, and username format. Users can only view their own jobs. If the root user executes the **atq** command, all jobs for all users are displayed.

19.2.4. Additional Command Line Options

Additional command line options for **at** and **batch** include:

Table 19.1. **at** and **batch** Command Line Options

Option	Description
-f	Read the commands or shell script from a file instead of specifying them at the prompt.
-m	Send email to the user when the job has been completed.
-v	Display the time that the job is executed.

19.2.5. Controlling Access to At and Batch

The **/etc/at.allow** and **/etc/at.deny** files can be used to restrict access to the **at** and **batch** commands. The format of both access control files is one username on each line. Whitespace is not permitted in either file. The **at** daemon (**atd**) does not have to be restarted if the access control files are modified. The access control files are read each time a user tries to execute the **at** or **batch** commands.

The root user can always execute **at** and **batch** commands, regardless of the access control files.

If the file **at.allow** exists, only users listed in it are allowed to use **at** or **batch**, and the **at.deny** file is ignored.

If **at.allow** does not exist, users listed in **at.deny** are not allowed to use **at** or **batch**.

19.2.6. Starting and Stopping the Service

To start the **at** service, use the following command as root:

```
systemctl start atd.service
```

To stop the service, as `root`, type the following at a shell prompt:

```
systemctl stop atd.service
```

It is recommended that you start the service at boot time. To do so, run the following command as `root`:

```
systemctl enable atd.service
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure services in Fedora.

19.3. Additional Resources

To learn more about configuring automated tasks, refer to the following resources.

19.3.1. Installed Documentation

- **`cron`** man page — contains an overview of cron.
- **`crontab`** man pages in sections 1 and 5 — The man page in section 1 contains an overview of the **`crontab`** file. The man page in section 5 contains the format for the file and some example entries.
- **`anacron`** man page — contains an overview of anacron.
- **`anacrontab`** man page — contains an overview of the **`anacrontab`** file.
- **`/usr/share/doc/at-`*`version`*`/timespec`** contains more detailed information about the times that can be specified for cron jobs.
- **`at`** man page — description of **`at`** and **`batch`** and their command line options.

OProfile

OProfile is a low overhead, system-wide performance monitoring tool. It uses the performance monitoring hardware on the processor to retrieve information about the kernel and executables on the system, such as when memory is referenced, the number of L2 cache requests, and the number of hardware interrupts received. On a Fedora system, the **oprofile** package must be installed to use this tool.

Many processors include dedicated performance monitoring hardware. This hardware makes it possible to detect when certain events happen (such as the requested data not being in cache). The hardware normally takes the form of one or more *counters* that are incremented each time an event takes place. When the counter value, essentially rolls over, an interrupt is generated, making it possible to control the amount of detail (and therefore, overhead) produced by performance monitoring.

OProfile uses this hardware (or a timer-based substitute in cases where performance monitoring hardware is not present) to collect *samples* of performance-related data each time a counter generates an interrupt. These samples are periodically written out to disk; later, the data contained in these samples can then be used to generate reports on system-level and application-level performance.

OProfile is a useful tool, but be aware of some limitations when using it:

- *Use of shared libraries* — Samples for code in shared libraries are not attributed to the particular application unless the **--separate=library** option is used.
- *Performance monitoring samples are inexact* — When a performance monitoring register triggers a sample, the interrupt handling is not precise like a divide by zero exception. Due to the out-of-order execution of instructions by the processor, the sample may be recorded on a nearby instruction.
- ***opreport** does not associate samples for inline functions properly* — **opreport** uses a simple address range mechanism to determine which function an address is in. Inline function samples are not attributed to the inline function but rather to the function the inline function was inserted into.
- *OProfile accumulates data from multiple runs* — OProfile is a system-wide profiler and expects processes to start up and shut down multiple times. Thus, samples from multiple runs accumulate. Use the command **opcontrol --reset** to clear out the samples from previous runs.
- *Hardware performance counters do not work on guest virtual machines* — Because the hardware performance counters are not available on virtual systems, you need to use the **timer** mode. Run the command **opcontrol --deinit**, and then execute **modprobe oprofile timer=1** to enable the **timer** mode.
- *Non-CPU-limited performance problems* — OProfile is oriented to finding problems with CPU-limited processes. OProfile does not identify processes that are asleep because they are waiting on locks or for some other event to occur (for example an I/O device to finish an operation).

20.1. Overview of Tools

Table 20.1, "OProfile Commands" provides a brief overview of the tools provided with the **oprofile** package.

Table 20.1. OProfile Commands

Command	Description
ophelp	Displays available events for the system's processor along with a brief description of each.
opimport	Converts sample database files from a foreign binary format to the native format for the system. Only use this option when analyzing a sample database from a different architecture.
opannotate	Creates annotated source for an executable if the application was compiled with debugging symbols. Refer to *Section 20.5.4, "Using **opannotate**"* for details.
opcontrol	Configures what data is collected. Refer to *Section 20.2, "Configuring OProfile"* for details.
opreport	Retrieves profile data. Refer to *Section 20.5.1, "Using **opreport**"* for details.
oprofiled	Runs as a daemon to periodically write sample data to disk.

20.2. Configuring OProfile

Before OProfile can be run, it must be configured. At a minimum, selecting to monitor the kernel (or selecting not to monitor the kernel) is required. The following sections describe how to use the **opcontrol** utility to configure OProfile. As the **opcontrol** commands are executed, the setup options are saved to the **/root/.oprofile/daemonrc** file.

20.2.1. Specifying the Kernel

First, configure whether OProfile should monitor the kernel. This is the only configuration option that is required before starting OProfile. All others are optional.

To monitor the kernel, execute the following command as root:

```
~]# opcontrol --setup --vmlinux=/usr/lib/debug/lib/modules/`uname -r`/vmlinux
```



Install the debuginfo package

The *debuginfo* package for the kernel must be installed (which contains the uncompressed kernel) in order to monitor the kernel.

To configure OProfile not to monitor the kernel, execute the following command as root:

```
~]# opcontrol --setup --no-vmlinux
```

This command also loads the **oprofile** kernel module, if it is not already loaded, and creates the **/dev/oprofile/** directory, if it does not already exist. Refer to *Section 20.6, "Understanding **/dev/oprofile/**"* for details about this directory.

Setting whether samples should be collected within the kernel only changes what data is collected, not how or where the collected data is stored. To generate different sample files for the kernel and application libraries, refer to *Section 20.2.3, "Separating Kernel and User-space Profiles"*.

20.2.2. Setting Events to Monitor

Most processors contain *counters*, which are used by OProfile to monitor specific events. As shown in *Table 20.2, "OProfile Processors and Counters"*, the number of counters available depends on the processor.

Table 20.2. OProfile Processors and Counters

Processor	cpu_type	Number of Counters
AMD64	x86-64/hammer	4
AMD Athlon	i386/athlon	4
AMD Family 10h	x86-64/family10	4
AMD Family 11h	x86-64/family11	4
AMD Family 12h	x86-64/family12	4
AMD Family 14h	x86-64/family14	4
AMD Family 15h	x86-64/family15	6
IBM eServer System i and IBM eServer System p	timer	1
IBM POWER4	ppc64/power4	8
IBM POWER5	ppc64/power5	6
IBM PowerPC 970	ppc64/970	8
IBM S/390 and IBM System z	timer	1
Intel Core i7	i386/core_i7	4
Intel Nehalem microarchitecture	i386/nehalem	4
Intel Pentium 4 (non-hyper-threaded)	i386/p4	8
Intel Pentium 4 (hyper-threaded)	i386/p4-ht	4
Intel Westmere microarchitecture	i386/westmere	4
TIMER_INT	timer	1

Use *Table 20.2, "OProfile Processors and Counters"* to verify that the correct processor type was detected and to determine the number of events that can be monitored simultaneously. **timer** is used as the processor type if the processor does not have supported performance monitoring hardware.

If **timer** is used, events cannot be set for any processor because the hardware does not have support for hardware performance counters. Instead, the timer interrupt is used for profiling.

If **timer** is not used as the processor type, the events monitored can be changed, and counter 0 for the processor is set to a time-based event by default. If more than one counter exists on the processor, the counters other than counter 0 are not set to an event by default. The default events monitored are shown in *Table 20.3, "Default Events"*.

Table 20.3. Default Events

Processor	Default Event for Counter	Description
AMD Athlon and AMD64	CPU_CLK_UNHALTED	The processor's clock is not halted
AMD Family 10h, AMD Family 11h, AMD Family 12h	CPU_CLK_UNHALTED	The processor's clock is not halted
AMD Family 14h, AMD Family 15h	CPU_CLK_UNHALTED	The processor's clock is not halted
IBM POWER4	CYCLES	Processor Cycles
IBM POWER5	CYCLES	Processor Cycles
IBM PowerPC 970	CYCLES	Processor Cycles
Intel Core i7	CPU_CLK_UNHALTED	The processor's clock is not halted
Intel Nehalem microarchitecture	CPU_CLK_UNHALTED	The processor's clock is not halted
Intel Pentium 4 (hyper-threaded and non-hyper-threaded)	GLOBAL_POWER_EVENTS	The time during which the processor is not stopped
Intel Westmere microarchitecture	CPU_CLK_UNHALTED	The processor's clock is not halted
TIMER_INT	(none)	Sample for each timer interrupt

The number of events that can be monitored at one time is determined by the number of counters for the processor. However, it is not a one-to-one correlation; on some processors, certain events must be mapped to specific counters. To determine the number of counters available, execute the following command:

```
~]# ls -d /dev/oprofile/[0-9]*
```

The events available vary depending on the processor type. To determine the events available for profiling, execute the following command as root (the list is specific to the system's processor type):

```
~]# ophelp
```

The events for each counter can be configured via the command line or with a graphical interface. For more information on the graphical interface, refer to *Section 20.9, "Graphical Interface"*. If the counter cannot be set to a specific event, an error message is displayed.

To set the event for each configurable counter via the command line, use **opcontrol**:

```
~]# opcontrol --event=event-name:sample-rate
```

Replace *event-name* with the exact name of the event from **ophelp**, and replace *sample-rate* with the number of events between samples.

20.2.2.1. Sampling Rate

By default, a time-based event set is selected. It creates a sample every 100,000 clock cycles per processor. If the timer interrupt is used, the timer is set to whatever the jiffy rate is and is not user-settable. If the **cpu_type** is not **timer**, each event can have a *sampling rate* set for it. The sampling rate is the number of events between each sample snapshot.

When setting the event for the counter, a sample rate can also be specified:

```
~]# opcontrol --event=event-name:sample-rate
```

Replace *sample-rate* with the number of events to wait before sampling again. The smaller the count, the more frequent the samples. For events that do not happen frequently, a lower count may be needed to capture the event instances.



Sampling too frequently can overload the system

Be extremely careful when setting sampling rates. Sampling too frequently can overload the system, causing the system to appear as if it is frozen or causing the system to actually freeze.

20.2.2.2. Unit Masks

Some user performance monitoring events may also require unit masks to further define the event.

Unit masks for each event are listed with the **ophelp** command. The values for each unit mask are listed in hexadecimal format. To specify more than one unit mask, the hexadecimal values must be combined using a bitwise *or* operation.

```
~]# opcontrol --event=event-name:sample-rate:unit-mask
```

20.2.3. Separating Kernel and User-space Profiles

By default, kernel mode and user mode information is gathered for each event. To configure OProfile to ignore events in kernel mode for a specific counter, execute the following command:

```
~]# opcontrol --event=event-name:sample-rate:unit-mask:0
```

Execute the following command to start profiling kernel mode for the counter again:

```
~]# opcontrol --event=event-name:sample-rate:unit-mask:1
```

To configure OProfile to ignore events in user mode for a specific counter, execute the following command:

```
~]# opcontrol --event=event-name:sample-rate:unit-mask:kernel:0
```

Execute the following command to start profiling user mode for the counter again:

```
~]# opcontrol --event=event-name:sample-rate:unit-mask:kernel:1
```

When the OProfile daemon writes the profile data to sample files, it can separate the kernel and library profile data into separate sample files. To configure how the daemon writes to sample files, execute the following command as root:

```
~]# opcontrol --separate=choice
```

choice can be one of the following:

- **none** — do not separate the profiles (default)
- **library** — generate per-application profiles for libraries
- **kernel** — generate per-application profiles for the kernel and kernel modules
- **all** — generate per-application profiles for libraries and per-application profiles for the kernel and kernel modules

If **--separate=library** is used, the sample file name includes the name of the executable as well as the name of the library.



Restart the OProfile profiler

These configuration changes will take effect when the OProfile profiler is restarted.

20.3. Starting and Stopping OProfile

To start monitoring the system with OProfile, execute the following command as root:

```
~]# opcontrol --start
```

Output similar to the following is displayed:

```
Using log file /var/lib/oprofile/oprofiled.log Daemon started. Profiler running.
```

The settings in **/root/.oprofile/daemonrc** are used.

The OProfile daemon, **oprofiled**, is started; it periodically writes the sample data to the **/var/lib/oprofile/samples/** directory. The log file for the daemon is located at **/var/lib/oprofile/oprofiled.log**.



Disable the nmi_watchdog registers

On a Fedora 17 system, the **nmi_watchdog** registers with the **perf** subsystem. Due to this, the **perf** subsystem grabs control of the performance counter registers at boot time, blocking OProfile from working.

To resolve this, either boot with the **nmi_watchdog=0** kernel parameter set, or run the following command to disable **nmi_watchdog** at run time:

```
~]# echo 0 > /proc/sys/kernel/nmi_watchdog
```

To re-enable **nmi_watchdog**, use the following command:

```
~]# echo 1 > /proc/sys/kernel/nmi_watchdog
```

To stop the profiler, execute the following command as root:

```
~]# opcontrol --shutdown
```

20.4. Saving Data

Sometimes it is useful to save samples at a specific time. For example, when profiling an executable, it may be useful to gather different samples based on different input data sets. If the number of events to be monitored exceeds the number of counters available for the processor, multiple runs of OProfile can be used to collect data, saving the sample data to different files each time.

To save the current set of sample files, execute the following command, replacing *name* with a unique descriptive name for the current session.

```
~]# opcontrol --save=name
```

The directory **/var/lib/oprofile/samples/*name*/** is created and the current sample files are copied to it.

20.5. Analyzing the Data

Periodically, the OProfile daemon, **oprofiled**, collects the samples and writes them to the **/var/lib/oprofile/samples/** directory. Before reading the data, make sure all data has been written to this directory by executing the following command as root:

```
~]# opcontrol --dump
```

Each sample file name is based on the name of the executable. For example, the samples for the default event on a Pentium III processor for **/bin/bash** becomes:

```
\{root\}/bin/bash/\{dep\}/\{root\}/bin/bash/CPU_CLK_UNHALTED.100000
```

The following tools are available to profile the sample data once it has been collected:

- **opreport**
- **opannotate**

Use these tools, along with the binaries profiled, to generate reports that can be further analyzed.



Back up the executable and the sample files

The executable being profiled must be used with these tools to analyze the data. If it must change after the data is collected, back up the executable used to create the samples as well as the sample files. Please note that the sample file and the binary have to agree. Making a backup is not going to work if they do not match. **oparchive** can be used to address this problem.

Samples for each executable are written to a single sample file. Samples from each dynamically linked library are also written to a single sample file. While OProfile is running, if the executable being monitored changes and a sample file for the executable exists, the existing sample file is automatically deleted. Thus, if the existing sample file is needed, it must be backed up, along with the executable used to create it before replacing the executable with a new version. The OProfile analysis tools use the executable file that created the samples during analysis. If the executable changes the analysis tools will be unable to analyze the associated samples. Refer to *Section 20.4, "Saving Data"* for details on how to back up the sample file.

20.5.1. Using opreport

The **opreport** tool provides an overview of all the executables being profiled.

The following is part of a sample output:

```
Profiling through timer interrupt
TIMER:0|
samples|      %|
------------------
25926 97.5212 no-vmlinux
359  1.3504 pi
65  0.2445 Xorg
62  0.2332 libvte.so.4.4.0
56  0.2106 libc-2.3.4.so
34  0.1279 libglib-2.0.so.0.400.7
19  0.0715 libXft.so.2.1.2
17  0.0639 bash
8  0.0301 ld-2.3.4.so
8  0.0301 libgdk-x11-2.0.so.0.400.13
6  0.0226 libgobject-2.0.so.0.400.7
5  0.0188 oprofiled
4  0.0150 libpthread-2.3.4.so
4  0.0150 libgtk-x11-2.0.so.0.400.13
3  0.0113 libXrender.so.1.2.2
3  0.0113 du
1  0.0038 libcrypto.so.0.9.7a
1  0.0038 libpam.so.0.77
1  0.0038 libtermcap.so.2.0.8
1  0.0038 libX11.so.6.2
1  0.0038 libgthread-2.0.so.0.400.7
```

```
1  0.0038 libwnck-1.so.4.9.0
```

Each executable is listed on its own line. The first column is the number of samples recorded for the executable. The second column is the percentage of samples relative to the total number of samples. The third column is the name of the executable.

Refer to the **opreport** man page for a list of available command line options, such as the **-r** option used to sort the output from the executable with the smallest number of samples to the one with the largest number of samples.

20.5.2. Using opreport on a Single Executable

To retrieve more detailed profiled information about a specific executable, use **opreport**:

```
~]# opreport mode executable
```

executable must be the full path to the executable to be analyzed. *mode* must be one of the following:

-l

List sample data by symbols. For example, the following is part of the output from running the command **opreport -l /lib/tls/libc-*version*.so**:

```
samples % symbol name
12 21.4286 __gconv_transform_utf8_internal
5 8.9286 _int_malloc 4 7.1429 malloc
3 5.3571 __i686.get_pc_thunk.bx
3 5.3571 _dl_mcount_wrapper_check
3 5.3571 mbrtowc
3 5.3571 memcpy
2 3.5714 _int_realloc
2 3.5714 _nl_intern_locale_data
2 3.5714 free
2 3.5714 strcmp
1 1.7857 __ctype_get_mb_cur_max
1 1.7857 __unregister_atfork
1 1.7857 __write_nocancel
1 1.7857 _dl_addr
1 1.7857 _int_free
1 1.7857 _itoa_word
1 1.7857 calc_eclosure_iter
1 1.7857 fopen@@GLIBC_2.1
1 1.7857 getpid
1 1.7857 memmove
1 1.7857 msort_with_tmp
1 1.7857 strcpy
1 1.7857 strlen
1 1.7857 vfprintf
1 1.7857 write
```

The first column is the number of samples for the symbol, the second column is the percentage of samples for this symbol relative to the overall samples for the executable, and the third column is the symbol name.

To sort the output from the largest number of samples to the smallest (reverse order), use **-r** in conjunction with the **-l** option.

-i *symbol-name*
List sample data specific to a symbol name. For example, the following output is from the command **opreport -l -i __gconv_transform_utf8_internal /lib/tls/libc-*version*.so**:

```
samples % symbol name
12 100.000 __gconv_transform_utf8_internal
```

The first line is a summary for the symbol/executable combination.

The first column is the number of samples for the memory symbol. The second column is the percentage of samples for the memory address relative to the total number of samples for the symbol. The third column is the symbol name.

-d
List sample data by symbols with more detail than **-l**. For example, the following output is from the command **opreport -l -d __gconv_transform_utf8_internal /lib/tls/libc-*version*.so**:

```
vma samples % symbol name
00a98640 12 100.000 __gconv_transform_utf8_internal
00a98640 1 8.3333
00a9868c 2 16.6667
00a9869a 1 8.3333
00a986c1 1 8.3333
00a98720 1 8.3333
00a98749 1 8.3333
00a98753 1 8.3333
00a98789 1 8.3333
00a98864 1 8.3333
00a98869 1 8.3333
00a98b08 1 8.3333
```

The data is the same as the **-l** option except that for each symbol, each virtual memory address used is shown. For each virtual memory address, the number of samples and percentage of samples relative to the number of samples for the symbol is displayed.

-x *symbol-name*
Exclude the comma-separated list of symbols from the output.

session:*name*
Specify the full path to the session or a directory relative to the **/var/lib/oprofile/samples/** directory.

20.5.3. Getting more detailed output on the modules

OProfile collects data on a system-wide basis for kernel- and user-space code running on the machine. However, once a module is loaded into the kernel, the information about the origin of the kernel module is lost. The module could have come from the **initrd** file on boot up, the directory with the various kernel modules, or a locally created kernel module. As a result, when OProfile records sample for a module, it just lists the samples for the modules for an executable in the root directory, but this is unlikely to be the place with the actual code for the module. You will need to take some steps to make sure that analysis tools get the executable.

To get a more detailed view of the actions of the module, you will need to either have the module "unstripped" (that is installed from a custom build) or have the *debuginfo* package installed for the kernel.

Find out which kernel is running with the **uname -a** command, obtain the appropriate *debuginfo* package and install it on the machine.

Then proceed with clearing out the samples from previous runs with the following command:

```
~]# opcontrol --reset
```

To start the monitoring process, for example, on a machine with Westmere processor, run the following command:

```
~]# opcontrol --setup --vmlinux=/usr/lib/debug/lib/modules/`uname -r`/vmlinux \
--event=CPU_CLK_UNHALTED:500000
```

Then the detailed information, for instance, for the ext4 module can be obtained with:

```
~]# opreport /ext4 -l --image-path /lib/modules/`uname -r`/kernel
CPU: Intel Westmere microarchitecture, speed 2.667e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No
 unit mask) count 500000
warning: could not check that the binary file /lib/modules/2.6.32-191.el6.x86_64/kernel/fs/
ext4/ext4.ko has not been modified since the profile was taken. Results may be inaccurate.
samples  %        symbol name
1622      9.8381  ext4_iget
1591      9.6500  ext4_find_entry
1231      7.4665  __ext4_get_inode_loc
783       4.7492  ext4_ext_get_blocks
752       4.5612  ext4_check_dir_entry
644       3.9061  ext4_mark_iloc_dirty
583       3.5361  ext4_get_blocks
583       3.5361  ext4_xattr_get
479       2.9053  ext4_htree_store_dirent
469       2.8447  ext4_get_group_desc
414       2.5111  ext4_dx_find_entry
```

20.5.4. Using opannotate

The **opannotate** tool tries to match the samples for particular instructions to the corresponding lines in the source code. The resulting files generated should have the samples for the lines at the left. It also puts in a comment at the beginning of each function listing the total samples for the function.

For this utility to work, the appropriate *debuginfo* package for the executable must be installed on the system. By default, Fedora *debuginfo* packages are not installed together with their corresponding packages, which contain the executable, so that you have to obtain and install the *debuginfo* packages separately.

The general syntax for **opannotate** is as follows:

```
~]# opannotate --search-dirs src-dir --source executable
```

The directory containing the source code and the executable to be analyzed must be specified. Refer to the **opannotate** man page for a list of additional command line options.

20.6. Understanding /dev/oprofile/

The **/dev/oprofile/** directory contains the file system for OProfile. Use the **cat** command to display the values of the virtual files in this file system. For example, the following command displays the type of processor OProfile detected:

```
~]# cat /dev/oprofile/cpu_type
```

A directory exists in **/dev/oprofile/** for each counter. For example, if there are 2 counters, the directories **/dev/oprofile/0/** and **dev/oprofile/1/** exist.

Each directory for a counter contains the following files:

- **count** — The interval between samples.
- **enabled** — If 0, the counter is off and no samples are collected for it; if 1, the counter is on and samples are being collected for it.
- **event** — The event to monitor.
- **extra** — Used on machines with Nehalem processors to further specify the event to monitor.
- **kernel** — If 0, samples are not collected for this counter event when the processor is in kernel-space; if 1, samples are collected even if the processor is in kernel-space.
- **unit_mask** — Defines which unit masks are enabled for the counter.
- **user** — If 0, samples are not collected for the counter event when the processor is in user-space; if 1, samples are collected even if the processor is in user-space.

The values of these files can be retrieved with the **cat** command. For example:

```
~]# cat /dev/oprofile/0/count
```

20.7. Example Usage

While OProfile can be used by developers to analyze application performance, it can also be used by system administrators to perform system analysis. For example:

- *Determine which applications and services are used the most on a system* — **opreport** can be used to determine how much processor time an application or service uses. If the system is used for multiple services but is under performing, the services consuming the most processor time can be moved to dedicated systems.
- *Determine processor usage* — The **CPU_CLK_UNHALTED** event can be monitored to determine the processor load over a given period of time. This data can then be used to determine if additional processors or a faster processor might improve system performance.

20.8. OProfile Support for Java

OProfile allows you to profile dynamically compiled code (also known as "just-in-time" or JIT code) of the Java Virtual Machine (JVM). OProfile in Fedora 17 includes build-in support for the JVM Tools Interface (JVMTI) agent library, which supports Java 1.5 and higher.

20.8.1. Profiling Java Code

To profile JIT code from the Java Virtual Machine with the JVMTI agent, add the following to the JVM startup parameters:

```
-agentlib:jvmti_oprofile
```



Install the oprofile-jit package

The *oprofile-jit* package must be installed on the system in order to profile JIT code with OProfile.

To learn more about Java support in OProfile, refer to the OProfile Manual, which is linked from *Section 20.11, "Additional Resources"*.

20.9. Graphical Interface

Some OProfile preferences can be set with a graphical interface. To start it, execute the **`oprof_start`** command as root at a shell prompt. To use the graphical interface, you will need to have the **`oprofile-gui`** package installed.

After changing any of the options, save them by clicking the **Save and quit** button. The preferences are written to **`/root/.oprofile/daemonrc`**, and the application exits. Exiting the application does not stop OProfile from sampling.

On the **Setup** tab, to set events for the processor counters as discussed in *Section 20.2.2, "Setting Events to Monitor"*, select the counter from the pulldown menu and select the event from the list. A brief description of the event appears in the text box below the list. Only events available for the specific counter and the specific architecture are displayed. The interface also displays whether the profiler is running and some brief statistics about it.

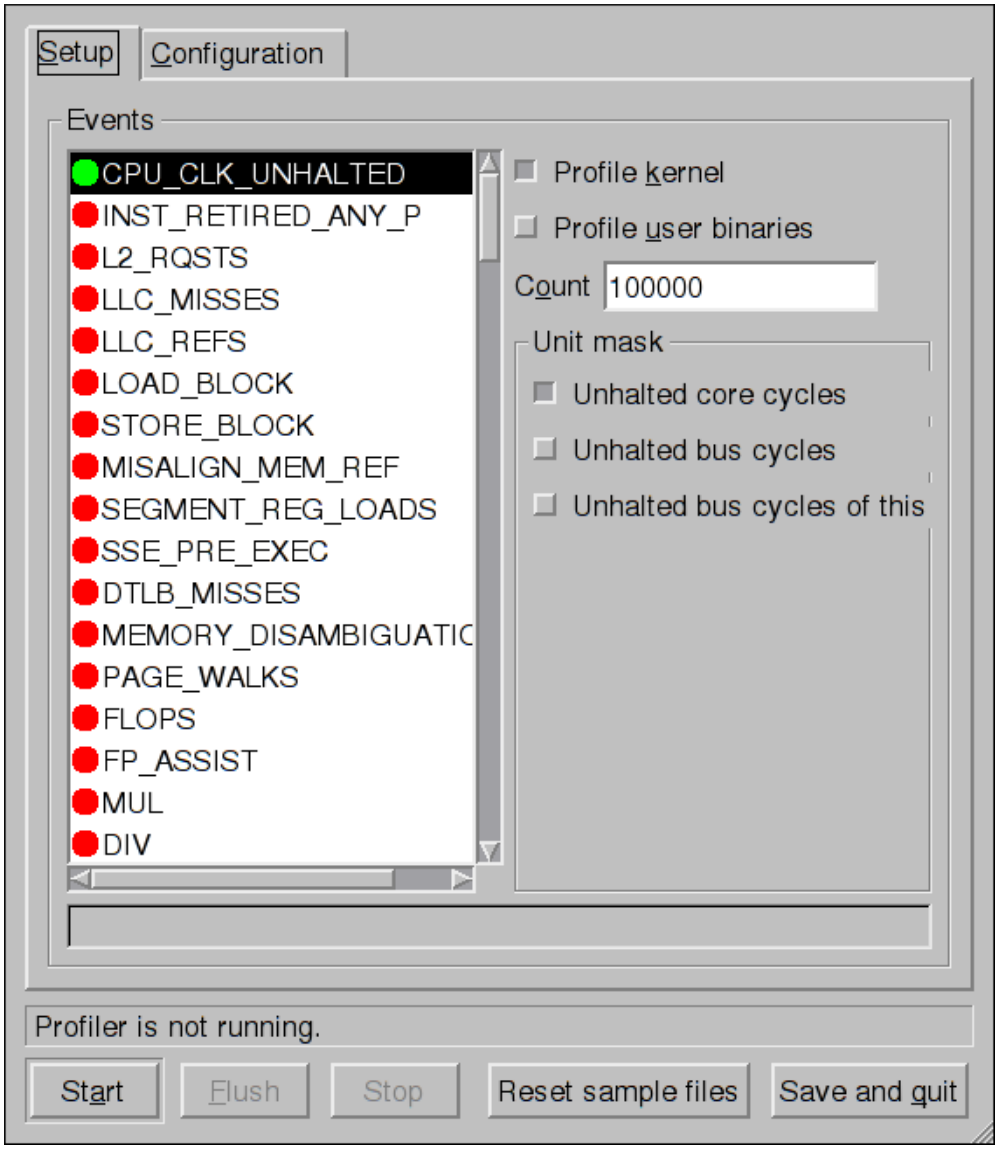


Figure 20.1. OProfile Setup

On the right side of the tab, select the **Profile kernel** option to count events in kernel mode for the currently selected event, as discussed in *Section 20.2.3, "Separating Kernel and User-space Profiles"*. If this option is unselected, no samples are collected for the kernel.

Select the **Profile user binaries** option to count events in user mode for the currently selected event, as discussed in *Section 20.2.3, "Separating Kernel and User-space Profiles"*. If this option is unselected, no samples are collected for user applications.

Use the **Count** text field to set the sampling rate for the currently selected event as discussed in *Section 20.2.2.1, "Sampling Rate"*.

If any unit masks are available for the currently selected event, as discussed in *Section 20.2.2.2, "Unit Masks"*, they are displayed in the **Unit Masks** area on the right side of the **Setup** tab. Select the checkbox beside the unit mask to enable it for the event.

On the **Configuration** tab, to profile the kernel, enter the name and location of the **`vmlinux`** file for the kernel to monitor in the **Kernel image file** text field. To configure OProfile not to monitor the kernel, select **No kernel image**.

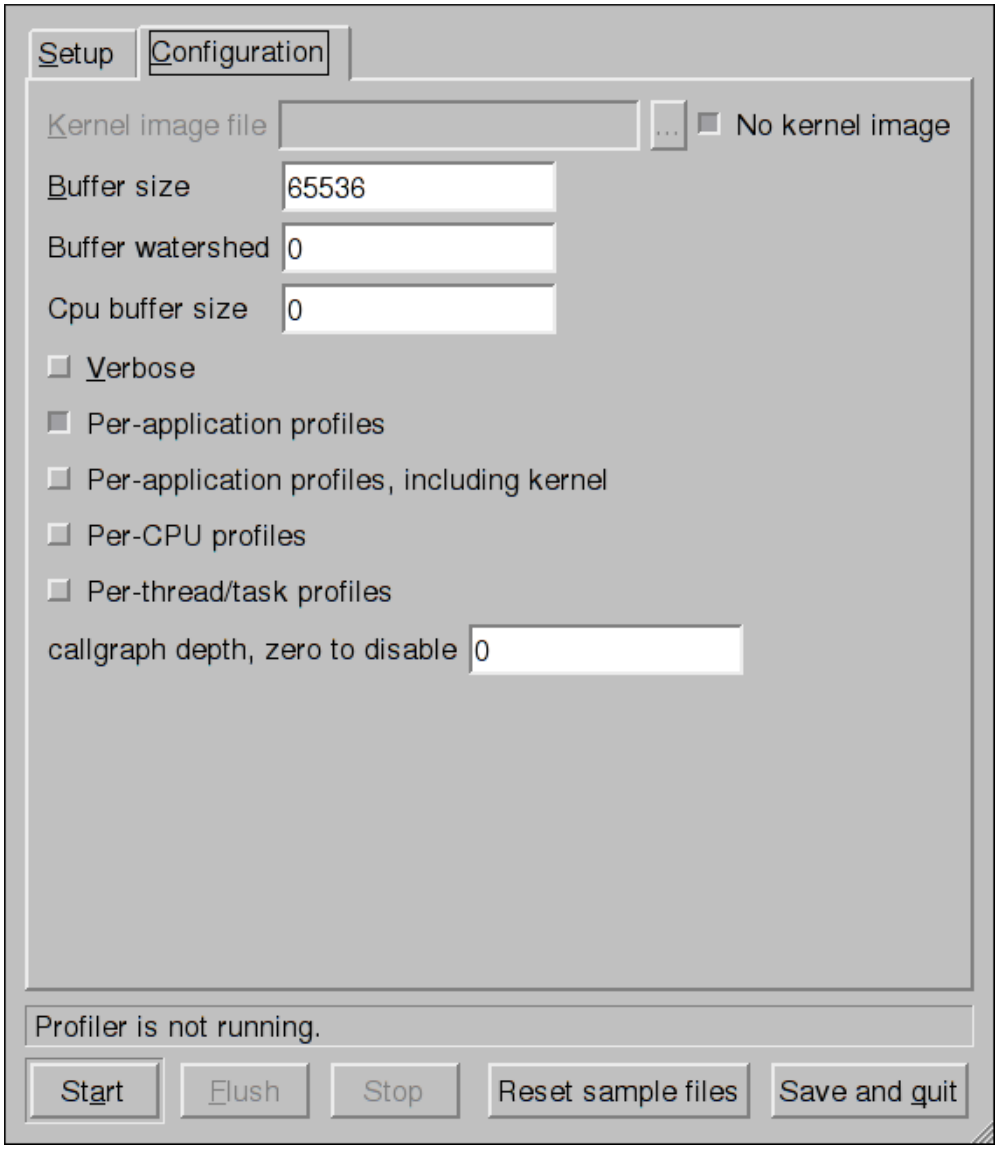


Figure 20.2. OProfile Configuration

If the **Verbose** option is selected, the **oprofiled** daemon log includes more information.

If **Per-application profiles** is selected, OProfile generates per-application profiles for libraries. This is equivalent to the **opcontrol --separate=library** command. If **Per-application profiles, including kernel** is selected, OProfile generates per-application profiles for the kernel and kernel modules as discussed in *Section 20.2.3, "Separating Kernel and User-space Profiles"*. This is equivalent to the **opcontrol --separate=kernel** command.

To force data to be written to samples files as discussed in *Section 20.5, "Analyzing the Data"*, click the **Flush** button. This is equivalent to the **opcontrol --dump** command.

To start OProfile from the graphical interface, click **Start**. To stop the profiler, click **Stop**. Exiting the application does not stop OProfile from sampling.

20.10. OProfile and SystemTap

SystemTap is a tracing and probing tool that allows users to study and monitor the activities of the operating system in fine detail. It provides information similar to the output of tools like **netstat**, **ps**,

top, and **iostat**; however, SystemTap is designed to provide more filtering and analysis options for collected information.

While using OProfile is suggested in cases of collecting data on where and why the processor spends time in a particular area of code, it is less usable when finding out why the processor stays idle.

You might want to use SystemTap when instrumenting specific places in code. Because SystemTap allows you to run the code instrumentation without having to stop and restart the instrumentation, it is particularly useful for instrumenting the kernel and daemons.

For more information on SystemTap, refer to *Section 20.11.2, "Useful Websites"* for the relevant SystemTap documentation.

20.11. Additional Resources

This chapter only highlights OProfile and how to configure and use it. To learn more, refer to the following resources.

20.11.1. Installed Docs

- **/usr/share/doc/oprofile-*version*/oprofile.html** — *OProfile Manual*
- **oprofile** man page — Discusses **opcontrol**, **opreport**, **opannotate**, and **ophelp**

20.11.2. Useful Websites

- *http://oprofile.sourceforge.net/* — Contains the latest documentation, mailing lists, IRC channels, and more.
- *SystemTap Beginners Guide*[1] — Provides basic instructions on how to use SystemTap to monitor different subsystems of Fedora in finer detail.

[1] http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/6/html/SystemTap_Beginners_Guide/index.html

Part VII. Kernel, Module and Driver Configuration

This part covers various tools that assist administrators with kernel customization.

Manually Upgrading the Kernel

The Fedora kernel is custom-built by the Fedora kernel team to ensure its integrity and compatibility with supported hardware. Before a kernel is released, it must first pass a rigorous set of quality assurance tests.

Fedora kernels are packaged in the RPM format so that they are easy to upgrade and verify using the **Yum** or **PackageKit** package managers. **PackageKit** automatically queries the Yum repositories and informs you of packages with available updates, including kernel packages.

This chapter is therefore *only* useful for users who need to manually update a kernel package using the **`rpm`** command instead of **`yum`**.



Use Yum to install kernels whenever possible

Whenever possible, use either the **Yum** or **PackageKit** package manager to install a new kernel because they always *install* a new kernel instead of replacing the current one, which could potentially leave your system unable to boot.

For more information on installing kernel packages with **Yum**, refer to *Section 4.1.2, "Updating Packages"*.

21.1. Overview of Kernel Packages

Fedora contains the following kernel packages:

- *kernel* — Contains the kernel for single, multicore and multiprocessor systems.
- *kernel-debug* — Contains a kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
- *kernel-devel* — Contains the kernel headers and makefiles sufficient to build modules against the *kernel* package.
- *kernel-debug-devel* — Contains the development version of the kernel with numerous debugging options enabled for kernel diagnosis, at the expense of reduced performance.
- *kernel-doc* — Documentation files from the kernel source. Various portions of the Linux kernel and the device drivers shipped with it are documented in these files. Installation of this package provides a reference to the options that can be passed to Linux kernel modules at load time.

  By default, these files are placed in the **`/usr/share/doc/kernel-doc-`*`kernel_version`*`/`** directory.
- *kernel-headers* — Includes the C header files that specify the interface between the Linux kernel and user-space libraries and programs. The header files define structures and constants that are needed for building most standard programs.
- *linux-firmware* — Contains all of the firmware files that are required by various devices to operate.

- *perf* — This package contains supporting scripts and documentation for the **perf** tool shipped in each kernel image subpackage.

21.2. Preparing to Upgrade

Before upgrading the kernel, it is recommended that you take some precautionary steps.

First, ensure that working boot media exists for the system in case a problem occurs. If the boot loader is not configured properly to boot the new kernel, the system cannot be booted into Fedora without working boot media.

USB media often comes in the form of flash devices sometimes called *pen drives*, *thumb disks*, or *keys*, or as an externally-connected hard disk device. Almost all media of this type is formatted as a VFAT file system. You can create bootable USB media on media formatted as `ext2`, `ext3`, `ext4`, or VFAT.

You can transfer a distribution image file or a minimal boot media image file to USB media. Make sure that sufficient free space is available on the device. Around `4 GB` is required for a distribution DVD image, around `700 MB` for a distribution CD image, or around `10 MB` for a minimal boot media image.

You must have a copy of the **`boot.iso`** file from a Fedora installation DVD, or installation CD-ROM#1, and you need a USB storage device formatted with the VFAT file system and around `16 MB` of free space. The following procedure will not affect existing files on the USB storage device unless they have the same path names as the files that you copy onto it. To create USB boot media, perform the following commands as the `root` user:

1. Install the **SYSLINUX** bootloader on the USB storage device:

   ```
   syslinux /dev/sdX1
   ```

   ...where *sdX* is the device name.

2. Create mount points for **`boot.iso`** and the USB storage device:

   ```
   mkdir /mnt/isoboot /mnt/diskboot
   ```

3. Mount **`boot.iso`**:

   ```
   mount -o loop boot.iso /mnt/isoboot
   ```

4. Mount the USB storage device:

   ```
   mount /dev/sdX1 /mnt/diskboot
   ```

5. Copy the **ISOLINUX** files from the **`boot.iso`** to the USB storage device:

   ```
   cp /mnt/isoboot/isolinux/* /mnt/diskboot
   ```

6. Use the **`isolinux.cfg`** file from **`boot.iso`** as the **`syslinux.cfg`** file for the USB device:

   ```
   grep -v local /mnt/isoboot/isolinux/isolinux.cfg > /mnt/diskboot/syslinux.cfg
   ```

7. Unmount **boot.iso** and the USB storage device:

```
umount /mnt/isoboot /mnt/diskboot
```

8. You should reboot the machine with the boot media and verify that you are able to boot with it before continuing.

Alternatively, on systems with a floppy drive, you can create a boot diskette by installing the *mkbootdisk* package and running the **mkbootdisk** command as `root`. Refer to **man mkbootdisk** man page after installing the package for usage information.

To determine which kernel packages are installed, execute the command **yum list installed "kernel-*"** at a shell prompt. The output will comprise some or all of the following packages, depending on the system's architecture, and the version numbers may differ:

```
~]# yum list installed "kernel-*"
Loaded plugins: langpacks, presto, refresh-packagekit
Installed Packages
kernel.x86_64            3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel.x86_64            3.1.0-0.rc9.git0.0.fc16        @updates-testing
kernel-doc.x86_64        3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel-doc.x86_64        3.1.0-0.rc9.git0.0.fc16        @updates-testing
kernel-headers.x86_64    3.1.0-0.rc6.git0.3.fc16        @updates-testing
kernel-headers.x86_64    3.1.0-0.rc9.git0.0.fc16        @updates-testing
```

From the output, determine which packages need to be downloaded for the kernel upgrade. For a single processor system, the only required package is the *kernel* package. Refer to *Section 21.1, "Overview of Kernel Packages"* for descriptions of the different packages.

21.3. Downloading the Upgraded Kernel

There are several ways to determine if an updated kernel is available for the system.

- Security Advisories — Refer to *http://fedoraproject.org/wiki/FSA* for information on Security Advisories, including kernel upgrades that fix security issues.
- Via Fedora Update System — Download and install the kernel RPM packages. For more information, refer to *http://admin.fedoraproject.org/updates/*.

To install the kernel manually, continue to *Section 21.4, "Performing the Upgrade"*.

21.4. Performing the Upgrade

After retrieving all of the necessary packages, it is time to upgrade the existing kernel.



Keep the old kernel when performing the upgrade

It is strongly recommended that you keep the old kernel in case there are problems with the new kernel.

At a shell prompt, change to the directory that contains the kernel RPM packages. Use **-i** argument with the **rpm** command to keep the old kernel. Do *not* use the **-U** option, since it overwrites the currently installed kernel, which creates boot loader problems. For example:

```
rpm -ivh kernel-kernel_version.arch.rpm
```

The next step is to verify that the initial RAM disk image has been created. Refer to *Section 21.5, "Verifying the Initial RAM Disk Image"* for details.

21.5. Verifying the Initial RAM Disk Image

The job of the initial RAM disk image is to preload the block device modules, such as for IDE, SCSI or RAID, so that the root file system, on which those modules normally reside, can then be accessed and mounted. On Fedora 17 systems, whenever a new kernel is installed using either the **Yum**, **PackageKit**, or **RPM** package manager, the **Dracut** utility is always called by the installation scripts to create an *initramfs* (initial RAM disk image).

On all architectures other than IBM eServer System i (see *Section 21.5, " Verifying the Initial RAM Disk Image and Kernel on IBM eServer System i "*), you can create an `initramfs` by running the **dracut** command. However, you usually don't need to create an `initramfs` manually: this step is automatically performed if the kernel and its associated packages are installed or upgraded from RPM packages distributed by The Fedora Project.

On architectures that use the GRUB 2 boot loader, you can verify that an `initramfs` corresponding to your current kernel version exists and is specified correctly in the **/boot/grub2/grub.cfg** configuration file by following this procedure:

Procedure 21.1. Verifying the Initial RAM Disk Image

1. As `root`, list the contents in the **/boot** directory and find the kernel (**vmlinuz-*kernel_version***) and **initramfs-*kernel_version*** with the latest (most recent) version number:

   ```
   ~]# ls /boot
   config-3.1.0-0.rc6.git0.3.fc16.x86_64
   config-3.1.0-0.rc9.git0.0.fc16.x86_64
   elf-memtest86+-4.20
   grub
   grub2
   initramfs-3.1.0-0.rc6.git0.3.fc16.x86_64.img
   initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img
   initrd-plymouth.img
   memtest86+-4.20
   System.map-3.1.0-0.rc6.git0.3.fc16.x86_64
   System.map-3.1.0-0.rc9.git0.0.fc16.x86_64
   vmlinuz-3.1.0-0.rc6.git0.3.fc16.x86_64
   vmlinuz-3.1.0-0.rc9.git0.0.fc16.x86_64
   ```

   The example above shows that:

   - we have two kernels installed (or, more correctly, two kernel files are present in the **/boot** directory),
   - the latest kernel is **vmlinuz-vmlinuz-3.1.0-0.rc9.git0.0.fc16.x86_64**, and
   - an `initramfs` file matching our kernel version, **initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img**, also exists.



initrd files in the /boot directory are not the same as initramfs files

In the **/boot** directory you may find several **initrd-<*kernel_version*>kdump.img** files. These are special files created by the `kdump` mechanism for kernel debugging purposes, are not used to boot the system, and can safely be ignored. For more information on `kdump`, refer to *Chapter 23, The kdump Crash Recovery Service*.

2. (Optional) If your **initramfs-*kernel_version*** file does not match the version of the latest kernel in **/boot**, or, in certain other situations, you may need to generate an **initramfs** file with the **Dracut** utility. Simply invoking **dracut** as `root` without options causes it to generate an **initramfs** file in the **/boot** directory for the latest kernel present in that directory:

```
~]# dracut
```

You must use the **--force** option if you want **dracut** to overwrite an existing **initramfs** (for example, if your **initramfs** has become corrupt). Otherwise **dracut** will refuse to overwrite the existing **initramfs** file:

```
~]# dracut
F: Will not override existing initramfs (/boot/
initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img) without --force
```

You can create an initramfs in the current directory by calling **dracut *initramfs_name kernel_version***, for example:

```
~]# dracut "initramfs-$(uname -r).img" $(uname -r)
```

If you need to specify specific kernel modules to be preloaded, add the names of those modules (minus any file name suffixes such as **.ko**) inside the parentheses of the **add_dracutmodules="*module* [*more_modules*]"** directive of the **/etc/dracut.conf** configuration file. You can list the file contents of an **initramfs** image file created by dracut by using the **lsinitrd *initramfs_file*** command:

```
~]# lsinitrd /boot/initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img
/boot/initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img: 16M
========================================================================
dracut-013-15.fc16
========================================================================
drwxr-xr-x   8 root     root        0 Oct 11 20:36 .
lrwxrwxrwx   1 root     root       17 Oct 11 20:36 lib -> run/initramfs/lib
drwxr-xr-x   2 root     root        0 Oct 11 20:36 sys
drwxr-xr-x   2 root     root        0 Oct 11 20:36 proc
lrwxrwxrwx   1 root     root       17 Oct 11 20:36 etc -> run/initramfs/etc
[output truncated]
```

Refer to **man dracut** and **man dracut.conf** for more information on options and usage.

3. Examine the **/boot/grub2/grub.cfg** configuration file to ensure that an **initrd */path/* initramfs-*kernel_version*.img** exists for the kernel version you are booting. For example:

```
~]# grep initrd /boot/grub2/grub.cfg
        initrd /initramfs-3.1.0-0.rc6.git0.3.fc16.x86_64.img
        initrd /initramfs-3.1.0-0.rc9.git0.0.fc16.x86_64.img
```

Refer to *Section 21.6, "Verifying the Boot Loader"* for more information on how to read and update the **/boot/grub2/grub.cfg** file.

Verifying the Initial RAM Disk Image and Kernel on IBM eServer System i

On IBM eServer System i machines, the initial RAM disk and kernel files are combined into a single file, which is created with the **addRamDisk** command. This step is performed automatically if the kernel and its associated packages are installed or upgraded from the RPM packages distributed by The Fedora Project; thus, it does not need to be executed manually. To verify that it was created, run the following command as `root` to make sure the **/boot/vmlinitrd-*kernel_version*** file already exists:

```
ls -l /boot
```

The *kernel_version* should match the version of the kernel just installed.

21.6. Verifying the Boot Loader

When you install a kernel using **rpm**, the kernel package creates an entry in the boot loader configuration file for that new kernel. However, **rpm** does *not* configure the new kernel to boot as the default kernel. You must do this manually when installing a new kernel with **rpm**.

It is always recommended to double-check the boot loader configuration file after installing a new kernel with **rpm** to ensure that the configuration is correct. Otherwise, the system may not be able to boot into Fedora properly. If this happens, boot the system with the boot media created earlier and re-configure the boot loader.

In the following table, find your system's architecture to determine the boot loader it uses, and then click on the "Refer to" link to jump to the correct instructions for your system.

Table 21.1. Boot loaders by architecture

Architecture	Boot Loader	Refer to
x86	GRUB 2	*Section 21.6.1, "Configuring the GRUB 2 Boot Loader"*
AMD AMD64 *or* Intel 64	GRUB 2	*Section 21.6.1, "Configuring the GRUB 2 Boot Loader"*
IBM eServer System i	OS/400	*Section 21.6.2, "Configuring the OS/400 Boot Loader"*
IBM eServer System p	YABOOT	*Section 21.6.3, "Configuring the YABOOT Boot Loader"*
IBM System z	z/IPL	—

21.6.1. Configuring the GRUB 2 Boot Loader

Fedora 17 is distributed with GRUB 2, which reads its configuration from the **/boot/grub2/grub.cfg** file. This file is generated by the **grub2-mkconfig** utility based on Linux kernels located in the **/boot** directory, template files located in **/etc/grub.d/**, and custom settings in the **/etc/default/grub** file and is automatically updated each time you install a new kernel from an RPM package. To update this configuration file manually, type the following at a shell prompt as `root`:

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

Among various code snippets and directives, the **/boot/grub2/grub.cfg** configuration file contains one or more **menuentry** blocks, each representing a single GRUB 2 boot menu entry. These blocks always start with the **menuentry** keyword followed by a title, list of options, and opening curly bracket, and end with a closing curly bracket. Anything between the opening and closing bracket should be indented. For example, the following is a sample **menuentry** block for Fedora 17 with Linux kernel 3.4.0-1.fc17.x86_64:

```
menuentry 'Fedora (3.4.0-1.fc17.x86_64)' --class fedora --class gnu-linux --class gnu --class
 os $menuentry_id_option 'gnulinux-simple-77ba9149-751a-48e0-974f-ad94911734b9' {
        load_video
        set gfxpayload=keep
        insmod gzio
        insmod part_msdos
        insmod ext2
        set root='hd0,msdos1'
        if [ x$feature_platform_search_hint = xy ]; then
          search --no-floppy --fs-uuid --set=root --hint='hd0,msdos1'  4ea24c68-
ab10-47d4-8a6b-b8d3a002acba
        else
          search --no-floppy --fs-uuid --set=root 4ea24c68-ab10-47d4-8a6b-b8d3a002acba
        fi
        echo 'Loading Fedora (3.4.0-1.fc17.x86_64)'
        linux   /vmlinuz-3.4.0-1.fc17.x86_64 root=/dev/mapper/vg_fedora-lv_root ro rd.md=0
 rd.dm=0 SYSFONT=True rd.lvm.lv=vg_fedora/lv_swap  KEYTABLE=us rd.lvm.lv=vg_fedora/lv_root
 rd.luks=0 LANG=en_US.UTF-8 rhgb quiet
        echo 'Loading initial ramdisk ...'
        initrd /initramfs-3.4.0-1.fc17.x86_64.img
}
```

Each **menuentry** block that represents an installed Linux kernel contains **linux** and **initrd** directives followed by the path to the kernel and the `initramfs` image respectively. If a separate **/boot** partition was created, the paths to the kernel and the `initramfs` image are relative to **/boot**. In the example above, the **initrd /initramfs-3.4.0-1.fc17.x86_64.img** line means that the `initramfs` image is actually located at **/boot/initramfs-3.4.0-1.fc17.x86_64.img** when the root file system is mounted, and likewise for the kernel path.

The kernel version number as given on the **linux /vmlinuz-*kernel_version*** line must match the version number of the `initramfs` image given on the **initrd /initramfs-*kernel_version*.img** line of each **menuentry** block. For more information on how to verify the initial RAM disk image, refer to *Procedure 21.1, "Verifying the Initial RAM Disk Image"*.



The initrd directive in grub.cfg refers to an initramfs image

In **menuentry** blocks, the **initrd** directive must point to the location (relative to the **/boot** directory if it is on a separate partition) of the **initramfs** file corresponding to the same kernel version. This directive is called **initrd** because the previous tool which created initial RAM disk images, **mkinitrd**, created what were known as `initrd` files. The **grub.cfg** directive remains `initrd` to maintain compatibility with other tools. The file-naming convention of systems using the **dracut** utility to create the initial RAM disk image is **initramfs-*kernel_version*.img**.

For information on using **Dracut**, refer to *Section 21.5, "Verifying the Initial RAM Disk Image"*.

After installing a new kernel with **rpm**, verify that **/boot/grub2/grub.cfg** is correct and reboot the computer into the new kernel. Ensure your hardware is detected by watching the boot process output. If GRUB 2 presents an error and is unable to boot into the new kernel, it is often easiest to try to boot into an alternative or older kernel so that you can fix the problem. Alternatively, use the boot media you created earlier to boot the system.



Causing the GRUB 2 boot menu to display

If you set the **GRUB_TIMEOUT** option in the **/etc/default/grub** file to `0`, GRUB 2 will not display its list of bootable kernels when the system starts up. In order to display this list when booting, press and hold any alphanumeric key while and immediately after BIOS information is displayed, and GRUB 2 will present you with the GRUB menu.

21.6.2. Configuring the OS/400 Boot Loader

The **/boot/vmlinitrd-*kernel-version*** file is installed when you upgrade the kernel. However, you must use the **dd** command to configure the system to boot the new kernel.

1. As `root`, issue the command **cat /proc/iSeries/mf/side** to determine the default side (either A, B, or C).

2. As `root`, issue the following command, where *`kernel-version`* is the version of the new kernel and *`side`* is the side from the previous command:

```
dd if=/boot/vmlinitrd-kernel-version of=/proc/iSeries/mf/side/vmlinux bs=8k
```

Begin testing the new kernel by rebooting the computer and watching the messages to ensure that the hardware is detected properly.

21.6.3. Configuring the YABOOT Boot Loader

IBM eServer System p uses YABOOT as its boot loader. YABOOT uses **/etc/aboot.conf** as its configuration file. Confirm that the file contains an **image** section with the same version as the *kernel* package just installed, and likewise for the `initramfs` image:

```
boot=/dev/sda1 init-message=Welcome to Fedora! Hit <TAB> for boot options
```

```
partition=2 timeout=30 install=/usr/lib/yaboot/yaboot delay=10 nonvram
image=/vmlinuz-2.6.32-17.EL
  label=old
  read-only
  initrd=/initramfs-2.6.32-17.EL.img
  append="root=LABEL=/"
image=/vmlinuz-2.6.32-19.EL
  label=linux
  read-only
  initrd=/initramfs-2.6.32-19.EL.img
  append="root=LABEL=/"
```

Notice that the default is not set to the new kernel. The kernel in the first image is booted by default. To change the default kernel to boot either move its image stanza so that it is the first one listed or add the directive **`default`** and set it to the **`label`** of the image stanza that contains the new kernel.

Begin testing the new kernel by rebooting the computer and watching the messages to ensure that the hardware is detected properly.

Working with Kernel Modules

The Linux kernel is modular, which means it can extend its capabilities through the use of dynamically-loaded *kernel modules*. A kernel module can provide:

- a device driver which adds support for new hardware; or,
- support for a file system such as `btrfs` or `NFS`.

Like the kernel itself, modules can take parameters that customize their behavior, though the default parameters work well in most cases. User-space tools can list the modules currently loaded into a running kernel; query all available modules for available parameters and module-specific information; and load or unload (remove) modules dynamically into or from a running kernel. Many of these utilities, which are provided by the *module-init-tools* package, take module dependencies into account when performing operations so that manual dependency-tracking is rarely necessary.

On modern systems, kernel modules are automatically loaded by various mechanisms when the conditions call for it. However, there are occasions when it is necessary to load and/or unload modules manually, such as when a module provides optional functionality, one module should be preferred over another although either could provide basic functionality, or when a module is misbehaving, among other situations.

This chapter explains how to:

- use the user-space *module-init-tools* package to display, query, load and unload kernel modules and their dependencies;
- set module parameters both dynamically on the command line and permanently so that you can customize the behavior of your kernel modules; and,
- load modules at boot time.



Installing the module-init-tools package

In order to use the kernel module utilities described in this chapter, first ensure the module-init-tools package is installed on your system by running, as `root`:

```
yum install module-init-tools
```

For more information on installing packages with Yum, refer to *Section 4.2.4, “Installing Packages”*.

22.1. Listing Currently-Loaded Modules

You can list all kernel modules that are currently loaded into the kernel by running the **`lsmod`** command, for example:

```
~]$ lsmod
Module                  Size  Used by
xfs                   803635  1
```

```
exportfs                3424  1 xfs
vfat                    8216  1
fat                    43410  1 vfat
tun                    13014  2
fuse                   54749  2
ip6table_filter         2743  0
ip6_tables             16558  1 ip6table_filter
ebtable_nat             1895  0
ebtables               15186  1 ebtable_nat
ipt_MASQUERADE          2208  6
iptable_nat             5420  1
nf_nat                 19059  2 ipt_MASQUERADE,iptable_nat
rfcomm                 65122  4
ipv6                  267017  33
sco                    16204  2
bridge                 45753  0
stp                     1887  1 bridge
llc                     4557  2 bridge,stp
bnep                   15121  2
l2cap                  45185  16 rfcomm,bnep
cpufreq_ondemand        8420  2
acpi_cpufreq            7493  1
freq_table              3851  2 cpufreq_ondemand,acpi_cpufreq
usb_storage            44536  1
sha256_generic         10023  2
aes_x86_64              7654  5
aes_generic            27012  1 aes_x86_64
cbc                     2793  1
dm_crypt               10930  1
kvm_intel              40311  0
kvm                   253162  1 kvm_intel
[output truncated]
```

Each row of **lsmod** output specifies:

- the name of a kernel module currently loaded in memory;
- the amount of memory it uses; and,
- the sum total of processes that are using the module and other modules which depend on it, followed by a list of the names of those modules, if there are any. Using this list, you can first unload all the modules depending the module you want to unload. For more information, refer to *Section 22.4, "Unloading a Module"*.

Finally, note that **lsmod** output is less verbose and considerably easier to read than the content of the **/proc/modules** pseudo-file.

22.2. Displaying Information About a Module

You can display detailed information about a kernel module by running the **modinfo *module_name*** command.



Module names do not end in .ko

When entering the name of a kernel module as an argument to one of the *module-init-tools* utilities, do not append a **.ko** extension to the end of the name. Kernel module names do not have extensions: their corresponding files do.

Example 22.1. Listing information about a kernel module with lsmod

To display information about the `e1000e` module, which is the Intel PRO/1000 network driver, run:

```
~]# modinfo e1000e
filename:       /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/net/e1000e/e1000e.ko
version:        1.2.7-k2
license:        GPL
description:    Intel(R) PRO/1000 Network Driver
author:         Intel Corporation, <linux.nics@intel.com>
srcversion:     93CB73D3995B501872B2982
alias:          pci:v00008086d00001503sv*sd*bc*sc*i*
alias:          pci:v00008086d00001502sv*sd*bc*sc*i*
[some alias lines omitted]
alias:          pci:v00008086d0000105Esv*sd*bc*sc*i*
depends:
vermagic:       2.6.32-71.el6.x86_64 SMP mod_unload modversions
parm:           copybreak:Maximum size of packet that is copied to a new buffer on receive
 (uint)
parm:           TxIntDelay:Transmit Interrupt Delay (array of int)
parm:           TxAbsIntDelay:Transmit Absolute Interrupt Delay (array of int)
parm:           RxIntDelay:Receive Interrupt Delay (array of int)
parm:           RxAbsIntDelay:Receive Absolute Interrupt Delay (array of int)
parm:           InterruptThrottleRate:Interrupt Throttling Rate (array of int)
parm:           IntMode:Interrupt Mode (array of int)
parm:           SmartPowerDownEnable:Enable PHY smart power down (array of int)
parm:           KumeranLockLoss:Enable Kumeran lock loss workaround (array of int)
parm:           WriteProtectNVM:Write-protect NVM [WARNING: disabling this can lead to
 corrupted NVM] (array of int)
parm:           CrcStripping:Enable CRC Stripping, disable if your BMC needs the CRC
 (array of int)
parm:           EEE:Enable/disable on parts that support the feature (array of int)
```

Here are descriptions of a few of the fields in **modinfo** output:

filename
: The absolute path to the **.ko** kernel object file. You can use **modinfo -n** as a shortcut command for printing only the **filename** field.

description
: A short description of the module. You can use **modinfo -d** as a shortcut command for printing only the description field.

alias
: The **alias** field appears as many times as there are aliases for a module, or is omitted entirely if there are none.

depends
: This field contains a comma-separated list of all the modules this module depends on.



Omitting the depends field

If a module has no dependencies, the **depends** field may be omitted from the output.

parm

Each **parm** field presents one module parameter in the form ***parameter_name*:*description***, where:

- *parameter_name* is the exact syntax you should use when using it as a module parameter on the command line, or in an option line in a **.conf** file in the **/etc/modprobe.d/** directory; and,
- *description* is a brief explanation of what the parameter does, along with an expectation for the type of value the parameter accepts (such as int, unit or array of int) in parentheses.

Example 22.2. Listing module parameters

You can list all parameters that the module supports by using the **-p** option. However, because useful value type information is omitted from **modinfo -p** output, it is more useful to run:

```
~]# modinfo e1000e | grep "^parm" | sort
parm:           copybreak:Maximum size of packet that is copied to a new buffer on
 receive (uint)
parm:           CrcStripping:Enable CRC Stripping, disable if your BMC needs the CRC
 (array of int)
parm:           EEE:Enable/disable on parts that support the feature (array of int)
parm:           InterruptThrottleRate:Interrupt Throttling Rate (array of int)
parm:           IntMode:Interrupt Mode (array of int)
parm:           KumeranLockLoss:Enable Kumeran lock loss workaround (array of int)
parm:           RxAbsIntDelay:Receive Absolute Interrupt Delay (array of int)
parm:           RxIntDelay:Receive Interrupt Delay (array of int)
parm:           SmartPowerDownEnable:Enable PHY smart power down (array of int)
parm:           TxAbsIntDelay:Transmit Absolute Interrupt Delay (array of int)
parm:           TxIntDelay:Transmit Interrupt Delay (array of int)
parm:           WriteProtectNVM:Write-protect NVM [WARNING: disabling this can lead to
 corrupted NVM] (array of int)
```

22.3. Loading a Module

To load a kernel module, run **modprobe *module_name*** as `root`. For example, to load the `wacom` module, run:

```
~]# modprobe wacom
```

By default, **modprobe** attempts to load the module from **/lib/modules/*kernel_version*/kernel/drivers/**. In this directory, each type of module has its own subdirectory, such as **net/** and **scsi/**, for network and SCSI interface drivers respectively.

Some modules have dependencies, which are other kernel modules that must be loaded before the module in question can be loaded. The **modprobe** command always takes dependencies into account when performing operations. When you ask **modprobe** to load a specific kernel module, it first examines the dependencies of that module, if there are any, and loads them if they are not already

loaded into the kernel. **modprobe** resolves dependencies recursively: it will load all dependencies of dependencies, and so on, if necessary, thus ensuring that all dependencies are always met.

You can use the **-v** (or **--verbose**) option to cause **modprobe** to display detailed information about what it is doing, which may include loading module dependencies.

Example 22.3. modprobe -v shows module dependencies as they are loaded

You can load the `Fibre Channel over Ethernet` module verbosely by typing the following at a shell prompt:

```
~]# modprobe -v fcoe
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/scsi_tgt.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/scsi_transport_fc.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/libfc/libfc.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/fcoe/libfcoe.ko
insmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/scsi/fcoe/fcoe.ko
```

In this example, you can see that **modprobe** loaded the `scsi_tgt`, `scsi_transport_fc`, `libfc` and `libfcoe` modules as dependencies before finally loading `fcoe`. Also note that **modprobe** used the more “primitive” **insmod** command to insert the modules into the running kernel.



Always use modprobe instead of insmod!

Although the **insmod** command can also be used to load kernel modules, it does not resolve dependencies. Because of this, you should *always* load modules using **modprobe** instead.

22.4. Unloading a Module

You can unload a kernel module by running **modprobe -r *module_name*** as `root`. For example, assuming that the `wacom` module is already loaded into the kernel, you can unload it by running:

```
~]# modprobe -r wacom
```

However, this command will fail if a process is using:

- the `wacom` module,
- a module that `wacom` directly depends on, or,
- any module that `wacom`—through the dependency tree—depends on indirectly.

Refer to *Section 22.1, “Listing Currently-Loaded Modules”* for more information about using **lsmod** to obtain the names of the modules which are preventing you from unloading a certain module.

Example 22.4. Unloading a kernel module

For example, if you want to unload the `firewire_ohci` module (because you believe there is a bug in it that is affecting system stability, for example), your terminal session might look similar to this:

```
~]# modinfo -F depends firewire_ohci
depends:        firewire-core
~]# modinfo -F depends firewire_core
depends:        crc-itu-t
~]# modinfo -F depends crc-itu-t
depends:
```

You have figured out the dependency tree (which does not branch in this example) for the loaded Firewire modules: `firewire_ohci` depends on `firewire_core`, which itself depends on `crc-itu-t`.

You can unload `firewire_ohci` using the **modprobe -v -r *module_name*** command, where **-r** is short for **--remove** and **-v** for **--verbose**:

```
~]# modprobe -r -v firewire_ohci
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/firewire/firewire-ohci.ko
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/drivers/firewire/firewire-core.ko
rmmod /lib/modules/2.6.32-71.el6.x86_64/kernel/lib/crc-itu-t.ko
```

The output shows that modules are unloaded in the reverse order that they are loaded, given that no processes depend on any of the modules being unloaded.



Do not use rmmod directly!

Although the **rmmod** command can be used to unload kernel modules, it is recommended to use **modprobe -r** instead.

22.5. Setting Module Parameters

Like the kernel itself, modules can also take parameters that change their behavior. Most of the time, the default ones work well, but occasionally it is necessary or desirable to set custom parameters for a module. Because parameters cannot be dynamically set for a module that is already loaded into a running kernel, there are two different methods for setting them.

1. You can unload all dependencies of the module you want to set parameters for, unload the module using **modprobe -r**, and then load it with **modprobe** along with a list of customized parameters. This method is often used when the module does not have many dependencies, or to test different combinations of parameters without making them persistent, and is the method covered in this section.

2. Alternatively, you can list the new parameters in an existing or newly-created file in the **/etc/modprobe.d/** directory. This method makes the module parameters persistent by ensuring that they are set each time the module is loaded, such as after every reboot or **modprobe** command. This method is covered in *Section 22.6, "Persistent Module Loading"*, though the following information is a prerequisite.

You can use **modprobe** to load a kernel module with custom parameters using the following command line format:

```
modprobe module_name [parameter=value]
```

When loading a module with custom parameters on the command line, be aware of the following:

- You can enter multiple parameters and values by separating them with spaces.
- Some module parameters expect a list of comma-separated values as their argument. When entering the list of values, do *not* insert a space after each comma, or **modprobe** will incorrectly interpret the values following spaces as additional parameters.
- The **modprobe** command silently succeeds with an exit status of `0` if:
  - it successfully loads the module, *or*
  - the module is *already* loaded into the kernel.

  Thus, you must ensure that the module is not already loaded before attempting to load it with custom parameters. The **modprobe** command does not automatically reload the module, or alert you that it is already loaded.

Here are the recommended steps for setting custom parameters and then loading a kernel module. This procedure illustrates the steps using the `e1000e` module, which is the network driver for Intel PRO/1000 network adapters, as an example:

Procedure 22.1. Loading a Kernel Module with Custom Parameters

1. First, ensure the module is not already loaded into the kernel. For example:

   ```
   ~]# lsmod | grep e1000e
   ~]#
   ```

   Output indicates that the module is already loaded into the kernel, in which case you must first unload it before proceeding. Refer to *Section 22.4, "Unloading a Module"* for instructions on safely unloading it.

2. Load the module and list all custom parameters after the module name. For example, if you wanted to load the Intel PRO/1000 network driver with the interrupt throttle rate set to 3000 interrupts per second for the first, second and third instances of the driver, and Energy Efficient Ethernet (EEE) turned on[1] , you would run, as `root`:

   ```
   ~]# modprobe e1000e InterruptThrottleRate=3000,3000,3000 EEE=1
   ```

   This example illustrates passing multiple valued to a single parameter by separating them with commas and omitting any spaces between them.

22.6. Persistent Module Loading

As shown in *Example 22.1, "Listing information about a kernel module with lsmod"*, many kernel modules are loaded automatically at boot time. You can specify additional modules to be loaded by creating a new ***file_name*.modules** file in the **/etc/sysconfig/modules/** directory, where *file_name* is any descriptive name of your choice. Your ***file_name*.modules** files are treated by

[1] Despite what the example might imply, Energy Efficient Ethernet is turned on by default in the `e1000e` driver.

the system startup scripts as shell scripts, and as such should begin with an *interpreter directive* (also called a “bang line”) as their first line:

```
#!/bin/sh
```

Additionally, the ***file_name*.modules** file should be executable. You can make it executable by running:

```
modules]# chmod +x file_name.modules
```

Example 22.5. /etc/sysconfig/modules/bluez-uinput.modules

The following **bluez-uinput.modules** script loads the `uinput` module:

```
#!/bin/sh

if [ ! -c /dev/input/uinput ] ; then
        exec /sbin/modprobe uinput >/dev/null 2>&1
fi
```

The **if**-conditional statement on the third line ensures that the **/dev/input/uinput** file does *not* already exist (the **!** symbol negates the condition), and, if that is the case, loads the `uinput` module by calling **exec /sbin/modprobe uinput**. Note that the `uinput` module creates the **/dev/input/uinput** file, so testing to see if that file exists serves as verification of whether the `uinput` module is loaded into the kernel.

The following **>/dev/null 2>&1** clause at the end of that line redirects any output to **/dev/null** so that the **modprobe** command remains quiet.

22.7. Specific Kernel Module Capabilities

This section explains how to enable specific kernel capabilities using various kernel modules.

22.7.1. Using Multiple Ethernet Cards

It is possible to use multiple Ethernet cards on a single machine. For each card there must be an **alias** and, possibly, **options** lines for each card in a user-created ***module_name*.conf** file in the **/etc/modprobe.d/** directory.

For additional information about using multiple Ethernet cards, refer to the *Linux Ethernet-HOWTO* online at *http://www.redhat.com/mirrors/LDP/HOWTO/Ethernet-HOWTO.html*.

22.7.2. Using Channel Bonding

Fedora allows administrators to bind NICs together into a single channel using the **bonding** kernel module and a special network interface, called a *channel bonding interface*. Channel bonding enables two or more network interfaces to act as one, simultaneously increasing the bandwidth and providing redundancy.

To channel bond multiple network interfaces, the administrator must perform the following steps:

1. As `root`, create a new file named ***bonding*`.conf`** in the **`/etc/modprobe.d/`** directory. Note that you can name this file anything you like as long as it ends with a **`.conf`** extension. Insert the following line in this new file:

   ```
   alias bondN bonding
   ```

   Replace *N* with the interface number, such as **`0`**. For each configured channel bonding interface, there must be a corresponding entry in your new **`/etc/modprobe.d/`*`bonding`*`.conf`** file.

2. Configure a channel bonding interface as outlined in *Section 7.2.2, "Channel Bonding Interfaces"*.

3. To enhance performance, adjust available module options to ascertain what combination works best. Pay particular attention to the **`miimon`** or **`arp_interval`** and the **`arp_ip_target`** parameters. Refer to *Section 22.7.2.1, "Bonding Module Directives"* for a list of available options and how to quickly determine the best ones for your bonded interface.

22.7.2.1. Bonding Module Directives

It is a good idea to test which channel bonding module parameters work best for your bonded interfaces before adding them to the *`BONDING_OPTS="bonding parameters"`* directive in your bonding interface configuration file (**`ifcfg-bond0`** for example). Parameters to bonded interfaces can be configured without unloading (and reloading) the bonding module by manipulating files in the `sysfs` file system.

`sysfs` is a virtual file system that represents kernel objects as directories, files and symbolic links. `sysfs` can be used to query for information about kernel objects, and can also manipulate those objects through the use of normal file system commands. The `sysfs` virtual file system has a line in **`/etc/fstab`**, and is mounted under the **`/sys/`** directory. All bonding interfaces can be configured dynamically by interacting with and manipulating files under the **`/sys/class/net/`** directory.

In order to determine the best parameters for your bonding interface, create a channel bonding interface file such as **`ifcfg-bond0`** by following the instructions in *Section 7.2.2, "Channel Bonding Interfaces"*. Insert the *`SLAVE=yes`* and *`MASTER=bond0`* directives in the configuration files for each interface bonded to bond0. Once this is completed, you can proceed to testing the parameters.

First, bring up the bond you created by running **`ifconfig bond`*`N`*` up`** as `root`:

```
~]# ifconfig bond0 up
```

If you have correctly created the **`ifcfg-bond0`** bonding interface file, you will be able to see **`bond0`** listed in the output of running **`ifconfig`** (without any options):

```
~]# ifconfig
bond0     Link encap:Ethernet HWaddr 00:00:00:00:00:00
          UP BROADCAST RUNNING MASTER MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:0 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 b)  TX bytes:0 (0.0 b)
eth0      Link encap:Ethernet  HWaddr 52:54:00:26:9E:F1
          inet addr:192.168.122.251  Bcast:192.168.122.255  Mask:255.255.255.0
          inet6 addr: fe80::5054:ff:fe26:9ef1/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:207 errors:0 dropped:0 overruns:0 frame:0
          TX packets:205 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:70374 (68.7 KiB)  TX bytes:25298 (24.7 KiB)
```

```
[output truncated]
```

To view all existing bonds, even if they are not up, run:

```
~]# cat /sys/class/net/bonding_masters
bond0
```

You can configure each bond individually by manipulating the files located in the **/sys/class/net/bond*N*/bonding/** directory. First, the bond you are configuring must be taken down:

```
~]# ifconfig bond0 down
```

As an example, to enable MII monitoring on bond0 with a 1 second interval, you could run (as `root`):

```
~]# echo 1000 > /sys/class/net/bond0/bonding/miimon
```

To configure bond0 for *balance-alb* mode, you could run either:

```
~]# echo 6 > /sys/class/net/bond0/bonding/mode
```

...or, using the name of the mode:

```
~]# echo balance-alb > /sys/class/net/bond0/bonding/mode
```

After configuring options for the bond in question, you can bring it up and test it by running **ifconfig bond*N* up** . If you decide to change the options, take the interface down, modify its parameters using `sysfs`, bring it back up, and re-test.

Once you have determined the best set of parameters for your bond, add those parameters as a space-separated list to the *BONDING_OPTS*= directive of the **/etc/sysconfig/network-scripts/ifcfg-bond*N*** file for the bonding interface you are configuring. Whenever that bond is brought up (for example, by the system during the boot sequence if the *ONBOOT=yes* directive is set), the bonding options specified in the *BONDING_OPTS* will take effect for that bond. For more information on configuring bonding interfaces (and *BONDING_OPTS*), refer to *Section 7.2.2, "Channel Bonding Interfaces"*.

The following list provides the names of many of the more common channel bonding parameters, along with a descriptions of what they do. For more information, refer to the brief descriptions for each **parm** in **modinfo bonding** output, or the exhaustive descriptions in the **bonding.txt** file in the *kernel-doc* package (see *Section 22.8, "Additional Resources"*).

Bonding Interface Parameters

arp_interval=*time_in_milliseconds*

Specifies (in milliseconds) how often ARP monitoring occurs.



Make sure you specify all required parameters

It is essential that both **arp_interval** and **arp_ip_target** parameters are specified, or, alternatively, the **miimon** parameter is specified. Failure to do so can cause degradation of network performance in the event that a link fails.

If using this setting while in **mode=0** or **mode=1** (the two load-balancing modes), the network switch must be configured to distribute packets evenly across the NICs. For more information on how to accomplish this, refer to **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/networking/bonding.txt**

The value is set to **0** by default, which disables it.

arp_ip_target=*ip_address*[,*ip_address_2*,…*ip_address_16*]
Specifies the target IP address of ARP requests when the **arp_interval** parameter is enabled. Up to 16 IP addresses can be specified in a comma separated list.

arp_validate=*value*
Validate source/distribution of ARP probes; default is **none**. Other valid values are **active**, **backup**, and **all**.

debug=*number*
Enables debug messages. Possible values are:

- **0** — Debug messages are disabled. This is the default.
- **1** — Debug messages are enabled.

downdelay=*time_in_milliseconds*
Specifies (in milliseconds) how long to wait after link failure before disabling the link. The value must be a multiple of the value specified in the **miimon** parameter. The value is set to **0** by default, which disables it.

lacp_rate=*value*
Specifies the rate at which link partners should transmit LACPDU packets in 802.3ad mode. Possible values are:

- **slow** or **0** — Default setting. This specifies that partners should transmit LACPDUs every 30 seconds.
- **fast** or **1** — Specifies that partners should transmit LACPDUs every 1 second.

miimon=*time_in_milliseconds*
Specifies (in milliseconds) how often MII link monitoring occurs. This is useful if high availability is required because MII is used to verify that the NIC is active. To verify that the driver for a particular NIC supports the MII tool, type the following command as `root`:

```
~]# ethtool interface_name | grep "Link detected:"
```

In this command, replace *interface_name* with the name of the device interface, such as **eth0**, not the bond interface. If MII is supported, the command returns:

```
Link detected: yes
```

If using a bonded interface for high availability, the module for each NIC must support MII. Setting the value to **0** (the default), turns this feature off. When configuring this setting, a good starting point for this parameter is **100**.



Make sure you specify all required parameters

It is essential that both **arp_interval** and **arp_ip_target** parameters are specified, or, alternatively, the **miimon** parameter is specified. Failure to do so can cause degradation of network performance in the event that a link fails.

mode=*value*

Allows you to specify the bonding policy. The *value* can be one of:

- **balance-rr** or **0** — Sets a round-robin policy for fault tolerance and load balancing. Transmissions are received and sent out sequentially on each bonded slave interface beginning with the first one available.
- **active-backup** or **1** — Sets an active-backup policy for fault tolerance. Transmissions are received and sent out via the first available bonded slave interface. Another bonded slave interface is only used if the active bonded slave interface fails.
- **balance-xor** or **2** — Sets an XOR (exclusive-or) policy for fault tolerance and load balancing. Using this method, the interface matches up the incoming request's MAC address with the MAC address for one of the slave NICs. Once this link is established, transmissions are sent out sequentially beginning with the first available interface.
- **broadcast** or **3** — Sets a broadcast policy for fault tolerance. All transmissions are sent on all slave interfaces.
- **802.3ad** or **4** — Sets an IEEE 802.3ad dynamic link aggregation policy. Creates aggregation groups that share the same speed and duplex settings. Transmits and receives on all slaves in the active aggregator. Requires a switch that is 802.3ad compliant.
- **balance-tlb** or **5** — Sets a Transmit Load Balancing (TLB) policy for fault tolerance and load balancing. The outgoing traffic is distributed according to the current load on each slave interface. Incoming traffic is received by the current slave. If the receiving slave fails, another slave takes over the MAC address of the failed slave.
- **balance-alb** or **6** — Sets an Active Load Balancing (ALB) policy for fault tolerance and load balancing. Includes transmit and receive load balancing for IPV4 traffic. Receive load balancing is achieved through ARP negotiation.

num_unsol_na=*number*

Specifies the number of unsolicited IPv6 Neighbor Advertisements to be issued after a failover event. One unsolicited NA is issued immediately after the failover.

The valid range is **0 - 255**; the default value is **1**. This parameter affects only the active-backup mode.

primary=*interface_name*

Specifies the interface name, such as **eth0**, of the primary device. The **primary** device is the first of the bonding interfaces to be used and is not abandoned unless it fails. This setting is particularly useful when one NIC in the bonding interface is faster and, therefore, able to handle a bigger load.

This setting is only valid when the bonding interface is in **active-backup** mode. Refer to **/usr/share/doc/kernel-doc-*kernel-version*/Documentation/networking/bonding.txt** for more information.

primary_reselect=*value*

Specifies the reselection policy for the primary slave. This affects how the primary slave is chosen to become the active slave when failure of the active slave or recovery of the primary slave occurs. This parameter is designed to prevent flip-flopping between the primary slave and other slaves. Possible values are:

- **always** or **0** (default) — The primary slave becomes the active slave whenever it comes back up.
- **better** or **1** — The primary slave becomes the active slave when it comes back up, if the speed and duplex of the primary slave is better than the speed and duplex of the current active slave.
- **failure** or **2** — The primary slave becomes the active slave only if the current active slave fails and the primary slave is up.

The **primary_reselect** setting is ignored in two cases:

- If no slaves are active, the first slave to recover is made the active slave.
- When initially enslaved, the primary slave is always made the active slave.

Changing the **primary_reselect** policy via `sysfs` will cause an immediate selection of the best active slave according to the new policy. This may or may not result in a change of the active slave, depending upon the circumstances

updelay=*time_in_milliseconds*

Specifies (in milliseconds) how long to wait before enabling a link. The value must be a multiple of the value specified in the **miimon** parameter. The value is set to **0** by default, which disables it.

use_carrier=*number*

Specifies whether or not **miimon** should use MII/ETHTOOL ioctls or `netif_carrier_ok()` to determine the link state. The `netif_carrier_ok()` function relies on the device driver to maintains its state with **netif_carrier_*on/off*** ; most device drivers support this function.

The MII/ETHROOL ioctls tools utilize a deprecated calling sequence within the kernel. However, this is still configurable in case your device driver does not support **netif_carrier_*on/off*** .

Valid values are:

- **1** — Default setting. Enables the use of `netif_carrier_ok()`.
- **0** — Enables the use of MII/ETHTOOL ioctls.



Note

If the bonding interface insists that the link is up when it should not be, it is possible that your network device driver does not support **netif_carrier_*on/off***.

xmit_hash_policy=*value*

Selects the transmit hash policy used for slave selection in **balance-xor** and **802.3ad** modes. Possible values are:

- **0** or **layer2** — Default setting. This parameter uses the XOR of hardware MAC addresses to generate the hash. The formula used is:

```
(source_MAC_address XOR destination_MAC) MODULO slave_count
```

This algorithm will place all traffic to a particular network peer on the same slave, and is 802.3ad compliant.

- **1** or **layer3+4** — Uses upper layer protocol information (when available) to generate the hash. This allows for traffic to a particular network peer to span multiple slaves, although a single connection will not span multiple slaves.

The formula for unfragmented TCP and UDP packets used is:

```
((source_port XOR dest_port) XOR
  ((source_IP XOR dest_IP) AND 0xffff)
    MODULO slave_count
```

For fragmented TCP or UDP packets and all other IP protocol traffic, the source and destination port information is omitted. For non-IP traffic, the formula is the same as the **layer2** transmit hash policy.

This policy intends to mimic the behavior of certain switches; particularly, Cisco switches with PFC2 as well as some Foundry and IBM products.

The algorithm used by this policy is not 802.3ad compliant.

- **2** or **layer2+3** — Uses a combination of layer2 and layer3 protocol information to generate the hash.

Uses XOR of hardware MAC addresses and IP addresses to generate the hash. The formula is:

```
(((source_IP XOR dest_IP) AND 0xffff) XOR
  ( source_MAC XOR destination_MAC ))
    MODULO slave_count
```

This algorithm will place all traffic to a particular network peer on the same slave. For non-IP traffic, the formula is the same as for the layer2 transmit hash policy.

This policy is intended to provide a more balanced distribution of traffic than layer2 alone, especially in environments where a layer3 gateway device is required to reach most destinations.

This algorithm is 802.3ad compliant.

22.8. Additional Resources

For more information on kernel modules and their utilities, refer to the following resources.

22.8.1. Installed Documentation

There is a number of manual pages for various utilities related to the kernel modules:

man lsmod
The manual page for the **lsmod** command.

man modinfo
The manual page for the **modinfo** command.

man modprobe
The manual page for the **modprobe** command.

man rmmod
The manual page for the **rmmod** command.

man ethtool
The manual page for the **ethtool** command.

man mii-tool
The manual page for the **mii-tool** command.

Additionally, you can refer to the documentation provided by the *kernel-doc* package:

/usr/share/doc/kernel-doc-*kernel_version*/Documentation/
This directory contains information on the kernel, kernel modules, and their respective parameters. Note that before accessing the kernel documentation, you must run the following command as `root`:

```
yum install kernel-doc
```

22.8.2. Useful Websites

Linux Loadable Kernel Module HOWTO[2]
The *Linux Loadable Kernel Module HOWTO* from the Linux Documentation Project contains further information on working with kernel modules.

[2] http://tldp.org/HOWTO/Module-HOWTO/

The kdump Crash Recovery Service

When the kdump crash dumping mechanism is enabled, the system is booted from the context of another kernel. This second kernel reserves a small amount of memory and its only purpose is to capture the core dump image in case the system crashes.

Being able to analyze the core dump significantly helps to determine the exact cause of the system failure, and it is therefore strongly recommended to have this feature enabled. This chapter explains how to configure, test, and use the kdump service in Fedora, and provides a brief overview of how to analyze the resulting core dump using the **crash** debugging utility.

23.1. Installing the kdump Service

In order use the kdump service on your system, make sure you have the *kexec-tools* package installed. To do so, type the following at a shell prompt as root:

```
yum install kexec-tools
```

For more information on how to install new packages in Fedora, refer to *Section 4.2.4, "Installing Packages"*.

23.2. Configuring the kdump Service

There are three common means of configuring the kdump service: at the first boot, using the **Kernel Dump Configuration** graphical utility, and doing so manually on the command line.



Disable IOMMU on Intel chipsets

A limitation in the current implementation of the Intel IOMMU driver can occasionally prevent the kdump service from capturing the core dump image. To use kdump on Intel architectures reliably, it is advised that the IOMMU support is disabled.

23.2.1. Configuring the kdump at First Boot

When the system boots for the first time, the **firstboot** application is launched to guide the user through the initial configuration of the freshly installed system. To configure kdump, navigate to the **Kdump** section and follow the instructions below.



Make sure the system has enough memory

Unless the system has enough memory, this option will not be available. For the information on minimum memory requirements, refer to the *Hardware Overview*[1] section of the *Fedora 17 Release Notes*[2]. When the `kdump` crash recovery is enabled, the minimum memory requirements increase by the amount of memory reserved for it. This value is determined by the user, and defaults to 128 MB plus 64 MB for each TB of physical memory (that is, a total of 192 MB for a system with 1 TB of physical memory).

23.2.1.1. Enabling the Service

To allow the `kdump` daemon to start at boot time, select the **Enable kdump?** checkbox. This will enable the service and start it for the current session. Similarly, unselecting the checkbox will disable it for and stop the service immediately.

23.2.1.2. Configuring the Memory Usage

To configure the amount of memory that is reserved for the `kdump` kernel, click the up and down arrow buttons next to the **Kdump Memory** field to increase or decrease the value. Notice that the **Usable System Memory** field changes accordingly showing you the remaining memory that will be available to the system.

23.2.2. Using the Kernel Dump Configuration Utility

To start the **Kernel Dump Configuration** utility, select **Applications□□□ Other□□□ Kernel crash dumps** from the **Activities** menu, or type **`system-config-kdump`** at a shell prompt. You will be presented with a window as shown in *Figure 23.1, "Basic Settings"*.

The utility allows you to configure `kdump` as well as to enable or disable starting the service at boot time. When you are done, click **Apply** to save the changes. The system reboot will be requested, and unless you are already authenticated, you will be prompted to enter the superuser password.

[1] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/sect-Release_Notes-Welcome_to_Fedora_17.html#sect-Release_Notes-Hardware_Overview
[2] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/index.html



Make sure the system has enough memory

Unless the system has enough memory, this option will not be available. For the information on minimum memory requirements, refer to the *Hardware Overview*[3] section of the *Fedora 17 Release Notes*[4]. When the `kdump` crash recovery is enabled, the minimum memory requirements increase by the amount of memory reserved for it. This value is determined by the user, and defaults to 128 MB plus 64 MB for each TB of physical memory (that is, a total of 192 MB for a system with 1 TB of physical memory).

23.2.2.1. Enabling the Service

To start the `kdump` daemon at boot time, click the **Enable** button on the toolbar. This will enable the service and start it for the current session. Similarly, clicking the **Disable** button will disable it and stop the service immediately.

For more information on system services and their configuration, refer to *Chapter 8, Services and Daemons*.

23.2.2.2. The Basic Settings Tab

The **Basic Settings** tab enables you to configure the amount of memory that is reserved for the `kdump` kernel. To do so, select the **Manual kdump memory settings** radio button, and click the up and down arrow buttons next to the **New kdump Memory** field to increase or decrease the value. Notice that the **Usable Memory** field changes accordingly showing you the remaining memory that will be available to the system.

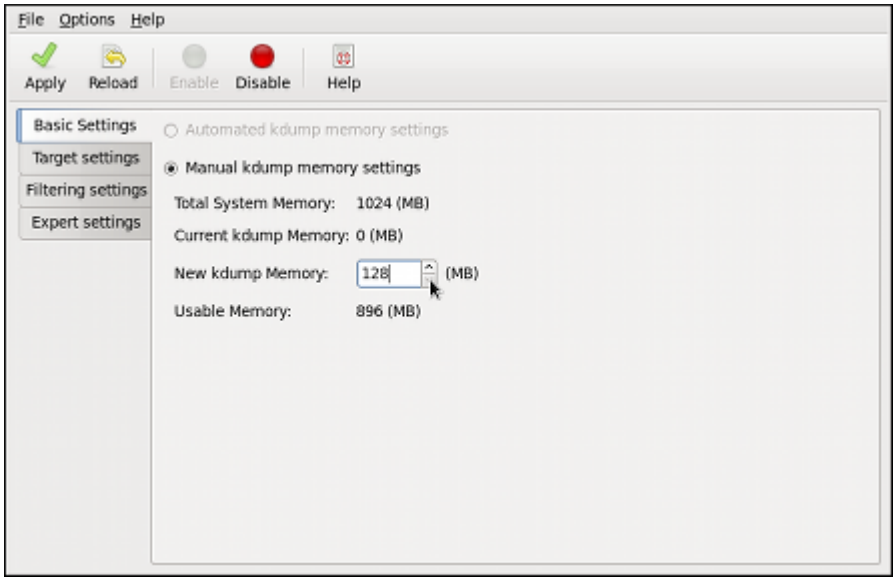


Figure 23.1. Basic Settings

[3] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/sect-Release_Notes-Welcome_to_Fedora_17.html#sect-Release_Notes-Hardware_Overview
[4] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/index.html

23.2.2.3. The Target Settings Tab

The **Target Settings** tab enables you to specify the target location for the **vmcore** dump. It can be either stored as a file in a local file system, written directly to a device, or sent over a network using the NFS (Network File System) or SSH (Secure Shell) protocol.

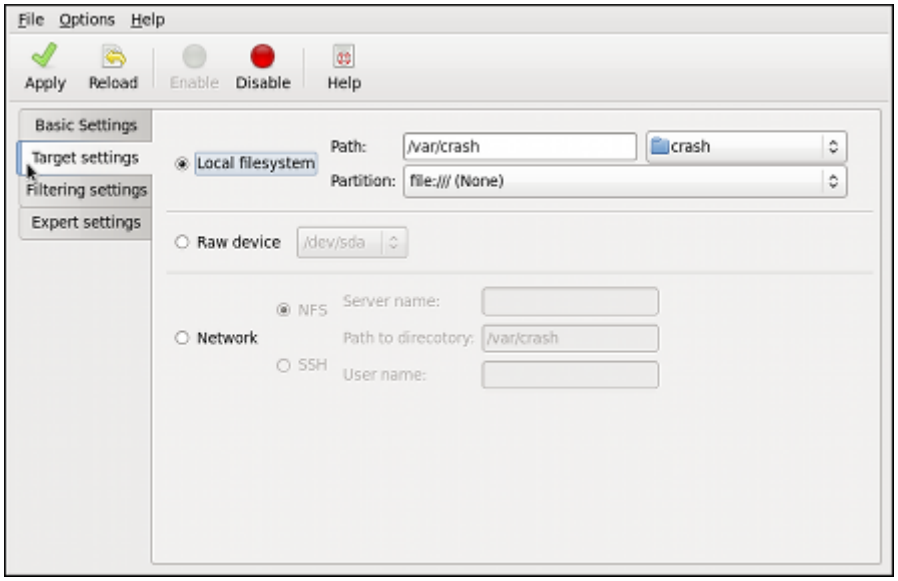


Figure 23.2. Target Settings

To save the dump to the local file system, select the **Local filesystem** radio button. Optionally, you can customize the settings by choosing a different partition from the **Partition**, and a target directory from the **Path** pulldown lists.

To write the dump directly to a device, select the **Raw device** radio button, and choose the desired target device from the pulldown list next to it.

To store the dump to a remote machine, select the **Network** radio button. To use the NFS protocol, select the **NFS** radio button, and fill the **Server name** and **Path to directory** fields. To use the SSH protocol, select the **SSH** radio button, and fill the **Server name**, **Path to directory**, and **User name** fields with the remote server address, target directory, and a valid remote user name respectively. Refer to *Chapter 10, OpenSSH* for information on how to configure an SSH server, and how to set up a key-based authentication.

For a complete list of currently supported targets, see *Table 23.1, "Supported kdump targets"*.

Table 23.1. Supported kdump targets

Type	Supported Targets	Unsupported Targets
Raw device	All locally attached raw disks and partitions.	—
Local file system	`ext2`, `ext3`, `ext4`, `minix` file systems on directly attached disk drives, hardware RAID logical drives, LVM devices, and `mdraid` arrays.	The `eCryptfs` file system.
Remote directory	Remote directories accessed using the NFS or SSH protocol over `IPv4`.	Remote directories on the `rootfs` file system accessed using the NFS protocol.

Type	Supported Targets	Unsupported Targets
	Remote directories accessed using the `iSCSI` protocol over hardware initiators.	Remote directories accessed using the `iSCSI` protocol over software initiators.
	—	Remote directories accessed over `IPv6`.
		Remote directories accessed using the `SMB/CIFS` protocol.
		Remote directories accessed using the `FCoE` (*Fibre Channel over Ethernet*) protocol.
		Remote directories accessed using wireless network interfaces.
		Multipath-based storages.

23.2.2.4. The Filtering Settings Tab

The **Filtering Settings** tab enables you to select the filtering level for the **`vmcore`** dump.

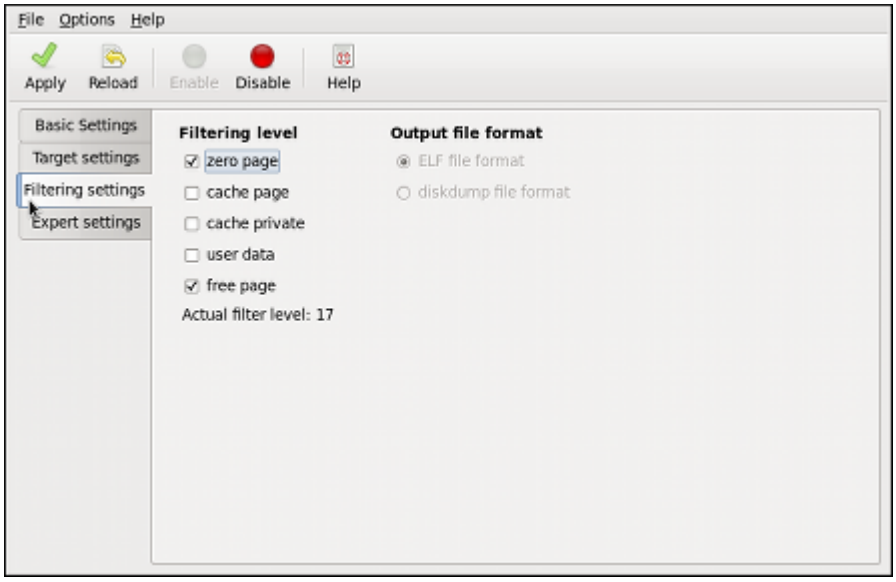


Figure 23.3. Filtering Settings

To exclude the **zero page**, **cache page**, **cache private**, **user data**, or **free page** from the dump, select the checkbox next to the appropriate label.

23.2.2.5. The Expert Settings Tab

The **Expert Settings** tab enables you to choose which kernel and initial RAM disk to use, as well as to customize the options that are passed to the kernel and the core collector program.

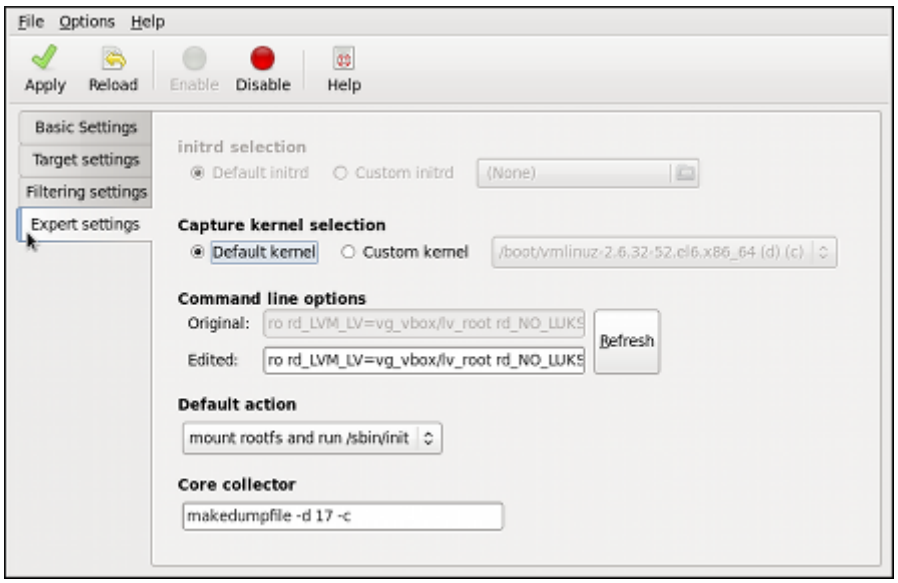


Figure 23.4. Expert Settings

To use a different initial RAM disk, select the **Custom initrd** radio button, and choose the desired RAM disk from the pulldown list next to it.

To capture a different kernel, select the **Custom kernel** radio button, and choose the desired kernel image from the pulldown list on the right.

To adjust the list of options that are passed to the kernel at boot time, edit the content of the **Edited** text field. Note that you can always revert your changes by clicking the **Refresh** button.

To choose what action to perform when `kdump` fails to create a core dump, select an appropriate option from the **Default action** pulldown list. Available options are **mount rootfs and run /sbin/init** (the default action), **reboot** (to reboot the system), **shell** (to present a user with an interactive shell prompt), **halt** (to halt the system), and **poweroff** (to power the system off).

To customize the options that are passed to the **`makedumpfile`** core collector, edit the **Core collector** text field; see *Section 23.2.3.3, "Configuring the Core Collector"* for more information.

23.2.3. Configuring kdump on the Command Line

23.2.3.1. Configuring the Memory Usage

To configure the amount of memory that is reserved for the `kdump` kernel, as `root`, edit the **`/etc/default/grub`** file and add the **`crashkernel=<size>M`** (or **`crashkernel=auto`**) parameter to the list of kernel options (the **`GRUB_CMDLINE_LINUX`** line). For example, to reserve 128 MB of memory, use:

```
GRUB_CMDLINE_LINUX="crashkernel=128M quiet rhgb"
```

Then update the configuration file for the GRUB 2 boot loader by typing the following at a shell prompt as `root`:

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```



Make sure the system has enough memory

Unless the system has enough memory, this option will not be available. For the information on minimum memory requirements, refer to the *Hardware Overview*[5] section of the *Fedora 17 Release Notes*[6]. When the `kdump` crash recovery is enabled, the minimum memory requirements increase by the amount of memory reserved for it. This value is determined by the user, and defaults to 128 MB plus 64 MB for each TB of physical memory (that is, a total of 192 MB for a system with 1 TB of physical memory).



Using the crashkernel=auto parameter

In Fedora 17, the **`crashkernel=auto`** only reserves memory if the system has 4 GB of physical memory or more.

23.2.3.2. Configuring the Target Type

When a kernel crash is captured, the core dump can be either stored as a file in a local file system, written directly to a device, or sent over a network using the NFS (Network File System) or SSH (Secure Shell) protocol. Only one of these options can be set at the moment, and the default option is to store the **`vmcore`** file in the **`/var/crash/`** directory of the local file system. To change this, as `root`, open the **`/etc/kdump.conf`** configuration file in a text editor and edit the options as described below.

To change the local directory in which the core dump is to be saved, remove the hash sign ("#") from the beginning of the **`#path /var/crash`** line, and replace the value with a desired directory path. Optionally, if you wish to write the file to a different partition, follow the same procedure with the **`#ext4 /dev/sda3`** line as well, and change both the file system type and the device (a device name, a file system label, and UUID are all supported) accordingly. For example:

```
ext3 /dev/sda4
path /usr/local/cores
```

To write the dump directly to a device, remove the hash sign ("#") from the beginning of the **`#raw /dev/sda5`** line, and replace the value with a desired device name. For example:

```
raw /dev/sdb1
```

[5] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/sect-Release_Notes-Welcome_to_Fedora_17.html#sect-Release_Notes-Hardware_Overview
[6] http://docs.fedoraproject.org/en-US/Fedora/17/html/Release_Notes/index.html

To store the dump to a remote machine using the NFS protocol, remove the hash sign (“#”) from the beginning of the **#net my.server.com:/export/tmp** line, and replace the value with a valid hostname and directory path. For example:

```
net penguin.example.com:/export/cores
```

To store the dump to a remote machine using the SSH protocol, remove the hash sign (“#”) from the beginning of the **#net user@my.server.com** line, and replace the value with a valid username and hostname. For example:

```
net john@penguin.example.com
```

Refer to *Chapter 10, OpenSSH* for information on how to configure an SSH server, and how to set up a key-based authentication.

For a complete list of currently supported targets, see *Table 23.1, “Supported kdump targets”*.

23.2.3.3. Configuring the Core Collector

To reduce the size of the **vmcore** dump file, `kdump` allows you to specify an external application (that is, a core collector) to compress the data, and optionally leave out all irrelevant information. Currently, the only fully supported core collector is **makedumpfile**.

To enable the core collector, as `root`, open the **/etc/kdump.conf** configuration file in a text editor, remove the hash sign (“#”) from the beginning of the **#core_collector makedumpfile -c --message-level 1 -d 31** line, and edit the command line options as described below.

To enable the dump file compression, add the **-c** parameter. For example:

```
core_collector makedumpfile -c
```

To remove certain pages from the dump, add the **-d *value*** parameter, where *value* is a sum of values of pages you want to omit as described in *Table 23.2, “Supported filtering levels”*. For example, to remove both zero and free pages, use the following:

```
core_collector makedumpfile -d 17 -c
```

Refer to the manual page for **makedumpfile** for a complete list of available options.

Table 23.2. Supported filtering levels

Option	Description
1	Zero pages
2	Cache pages
4	Cache private
8	User pages
16	Free pages

23.2.3.4. Changing the Default Action

By default, when `kdump` fails to create a core dump, the root file system is mounted and **`/sbin/init`** is run. To change this behavior, as `root`, open the **`/etc/kdump.conf`** configuration file in a text editor, remove the hash sign ("#") from the beginning of the **`#default shell`** line, and replace the value with a desired action as described in *Table 23.3, "Supported actions"*.

Table 23.3. Supported actions

Option	Description
`reboot`	Reboot the system, losing the core in the process.
`halt`	Halt the system.
`poweroff`	Power off the system.
`shell`	Run the **msh** session from within the initramfs, allowing a user to record the core manually.

For example:

```
default halt
```

23.2.3.5. Enabling the Service

To start the `kdump` daemon at boot time, type the following at a shell prompt as `root`:

```
systemctl enable kdump.service
```

Similarly, typing **`systemctl disable kdump.service`** will disable it. To start the service in the current session, use the following command as `root`:

```
systemctl start kdump.service
```

For more information on services and their configuration, refer to *Chapter 8, Services and Daemons*.

23.2.4. Testing the Configuration



Be careful when using these commands

The commands below will cause the kernel to crash. Use caution when following these steps, and by no means use them on a production machine.

To test the configuration, reboot the system with `kdump` enabled, and make sure that the service is running (refer to *Section 8.2, "Running Services"* for more information on how to run a service in Fedora):

```
systemctl is-active kdump.service
```

Then type the following commands at a shell prompt:

```
echo 1 > /proc/sys/kernel/sysrq
echo c > /proc/sysrq-trigger
```

This will force the Linux kernel to crash, and the ***address-YYYY-MM-DD-HH:MM:SS*/vmcore** file will be copied to the location you have selected in the configuration (that is, to **/var/crash/** by default).

23.3. Analyzing the Core Dump

To determine the cause of the system crash, you can use the **crash** utility, which provides an interactive prompt very similar to the GNU Debugger (GDB). This utility allows you to interactively analyze a running Linux system as well as a core dump created by `netdump`, `diskdump`, `xendump`, or `kdump`.



Make sure you have relevant packages installed

To analyze the **vmcore** dump file, you must have the *crash* and *kernel-debuginfo* packages installed. To install these packages, type the following at a shell prompt as `root`:

```
yum install crash
debuginfo-install kernel
```

For more information on how to install new packages in Fedora, refer to *Section 4.2.4, "Installing Packages"*.

23.3.1. Running the crash Utility

To start the utility, type the command in the following form at a shell prompt:

```
crash /var/crash/timestamp/vmcore /usr/lib/debug/lib/modules/kernel/vmlinux
```

Note that the *kernel* version should be the same that was captured by `kdump`. To find out which kernel you are currently running, use the **uname -r** command.

Example 23.1. Running the crash utility

```
~]# crash /usr/lib/debug/lib/modules/2.6.32-69.el6.i686/vmlinux \
/var/crash/127.0.0.1-2010-08-25-08:45:02/vmcore

crash 5.0.0-23.el6
Copyright (C) 2002-2010  Red Hat, Inc.
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```

```
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GNU gdb (GDB) 7.0
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This GDB was configured as "i686-pc-linux-gnu"...

      KERNEL: /usr/lib/debug/lib/modules/2.6.32-69.el6.i686/vmlinux
    DUMPFILE: /var/crash/127.0.0.1-2010-08-25-08:45:02/vmcore  [PARTIAL DUMP]
        CPUS: 4
        DATE: Wed Aug 25 08:44:47 2010
      UPTIME: 00:09:02
LOAD AVERAGE: 0.00, 0.01, 0.00
       TASKS: 140
    NODENAME: hp-dl320g5-02.lab.bos.redhat.com
     RELEASE: 2.6.32-69.el6.i686
     VERSION: #1 SMP Tue Aug 24 10:31:45 EDT 2010
     MACHINE: i686  (2394 Mhz)
      MEMORY: 8 GB
       PANIC: "Oops: 0002 [#1] SMP " (check log for details)
         PID: 5591
     COMMAND: "bash"
        TASK: f196d560  [THREAD_INFO: ef4da000]
         CPU: 2
       STATE: TASK_RUNNING (PANIC)

crash>
```

23.3.2. Displaying the Message Buffer

To display the kernel message buffer, type the **log** command at the interactive prompt.

Example 23.2. Displaying the kernel message buffer

```
crash> log
... several lines omitted ...
EIP: 0060:[<c068124f>] EFLAGS: 00010096 CPU: 2
EIP is at sysrq_handle_crash+0xf/0x20
EAX: 00000063 EBX: 00000063 ECX: c09e1c8c EDX: 00000000
ESI: c0a09ca0 EDI: 00000286 EBP: 00000000 ESP: ef4dbf24
 DS: 007b ES: 007b FS: 00d8 GS: 00e0 SS: 0068
Process bash (pid: 5591, ti=ef4da000 task=f196d560 task.ti=ef4da000)
Stack:
 c068146b c0960891 c0968653 00000003 00000000 00000002 efade5c0 c06814d0
<0> fffffffb c068150f b7776000 f2600c40 c0569ec4 ef4dbf9c 00000002 b7776000
<0> efade5c0 00000002 b7776000 c0569e60 c051de50 ef4dbf9c f196d560 ef4dbfb4
Call Trace:
 [<c068146b>] ? __handle_sysrq+0xfb/0x160
 [<c06814d0>] ? write_sysrq_trigger+0x0/0x50
 [<c068150f>] ? write_sysrq_trigger+0x3f/0x50
 [<c0569ec4>] ? proc_reg_write+0x64/0xa0
 [<c0569e60>] ? proc_reg_write+0x0/0xa0
 [<c051de50>] ? vfs_write+0xa0/0x190
 [<c051e8d1>] ? sys_write+0x41/0x70
 [<c0409adc>] ? syscall_call+0x7/0xb
Code: a0 c0 01 0f b6 41 03 19 d2 f7 d2 83 e2 03 83 e0 cf c1 e2 04 09 d0 88 41 03 f3 c3 90
 c7 05 c8 1b 9e c0 01 00 00 00 0f ae f8 89 f6 <c6> 05 00 00 00 00 01 c3 89 f6 8d bc 27 00
 00 00 00 8d 50 d0 83
EIP: [<c068124f>] sysrq_handle_crash+0xf/0x20 SS:ESP 0068:ef4dbf24
```

```
CR2: 0000000000000000
```

Type **help log** for more information on the command usage.

23.3.3. Displaying a Backtrace

To display the kernel stack trace, type the **bt** command at the interactive prompt. You can use **bt *pid*** to display the backtrace of the selected process.

Example 23.3. Displaying the kernel stack trace

```
crash> bt
PID: 5591   TASK: f196d560  CPU: 2   COMMAND: "bash"
 #0 [ef4dbdcc] crash_kexec at c0494922
 #1 [ef4dbe20] oops_end at c080e402
 #2 [ef4dbe34] no_context at c043089d
 #3 [ef4dbe58] bad_area at c0430b26
 #4 [ef4dbe6c] do_page_fault at c080fb9b
 #5 [ef4dbee4] error_code (via page_fault) at c080d809
    EAX: 00000063  EBX: 00000063  ECX: c09e1c8c  EDX: 00000000  EBP: 00000000
    DS:  007b      ESI: c0a09ca0  ES:  007b      EDI: 00000286  GS:  00e0
    CS:  0060      EIP: c068124f  ERR: ffffffff  EFLAGS: 00010096
 #6 [ef4dbf18] sysrq_handle_crash at c068124f
 #7 [ef4dbf24] __handle_sysrq at c0681469
 #8 [ef4dbf48] write_sysrq_trigger at c068150a
 #9 [ef4dbf54] proc_reg_write at c0569ec2
#10 [ef4dbf74] vfs_write at c051de4e
#11 [ef4dbf94] sys_write at c051e8cc
#12 [ef4dbfb0] system_call at c0409ad5
    EAX: fffffffa  EBX: 00000001  ECX: b7776000  EDX: 00000002
    DS:  007b      ESI: 00000002  ES:  007b      EDI: b7776000
    SS:  007b      ESP: bfcb2088  EBP: bfcb20b4  GS:  0033
    CS:  0073      EIP: 00edc416  ERR: 00000004  EFLAGS: 00000246
```

Type **help bt** for more information on the command usage.

23.3.4. Displaying a Process Status

To display status of processes in the system, type the **ps** command at the interactive prompt. You can use **ps *pid*** to display the status of the selected process.

Example 23.4. Displaying status of processes in the system

```
crash> ps
   PID    PPID  CPU   TASK    ST  %MEM     VSZ    RSS  COMM
>     0      0   0  c09dc560  RU   0.0       0      0  [swapper]
>     0      0   1  f7072030  RU   0.0       0      0  [swapper]
      0      0   2  f70a3a90  RU   0.0       0      0  [swapper]
>     0      0   3  f70ac560  RU   0.0       0      0  [swapper]
      1      0   1  f705ba90  IN   0.0    2828   1424  init
... several lines omitted ...
   5566      1   1  f2592560  IN   0.0   12876    784  auditd
   5567      1   2  ef427560  IN   0.0   12876    784  auditd
   5587   5132   0  f196d030  IN   0.0   11064   3184  sshd
>  5591   5587   2  f196d560  RU   0.0    5084   1648  bash
```

Type **help ps** for more information on the command usage.

23.3.5. Displaying Virtual Memory Information

To display basic virtual memory information, type the **vm** command at the interactive prompt. You can use **vm *pid*** to display information on the selected process.

Example 23.5. Displaying virtual memory information of the current context

```
crash> vm
PID: 5591   TASK: f196d560  CPU: 2   COMMAND: "bash"
   MM       PGD      RSS    TOTAL_VM
f19b5900  ef9c6000  1648k    5084k
  VMA       START      END    FLAGS  FILE
f1bb0310    242000    260000 8000875  /lib/ld-2.12.so
f26af0b8    260000    261000 8100871  /lib/ld-2.12.so
efbc275c    261000    262000 8100873  /lib/ld-2.12.so
efbc2a18    268000    3ed000 8000075  /lib/libc-2.12.so
efbc23d8    3ed000    3ee000 8000070  /lib/libc-2.12.so
efbc2888    3ee000    3f0000 8100071  /lib/libc-2.12.so
efbc2cd4    3f0000    3f1000 8100073  /lib/libc-2.12.so
efbc243c    3f1000    3f4000 100073
efbc28ec    3f6000    3f9000 8000075  /lib/libdl-2.12.so
efbc2568    3f9000    3fa000 8100071  /lib/libdl-2.12.so
efbc2f2c    3fa000    3fb000 8100073  /lib/libdl-2.12.so
f26af888    7e6000    7fc000 8000075  /lib/libtinfo.so.5.7
f26aff2c    7fc000    7ff000 8100073  /lib/libtinfo.so.5.7
efbc211c    d83000    d8f000 8000075  /lib/libnss_files-2.12.so
efbc2504    d8f000    d90000 8100071  /lib/libnss_files-2.12.so
efbc2950    d90000    d91000 8100073  /lib/libnss_files-2.12.so
f26afe00    edc000    edd000 4040075
f1bb0a18   8047000   8118000 8001875  /bin/bash
f1bb01e4   8118000   811d000 8101873  /bin/bash
f1bb0c70   811d000   8122000 100073
f26afae0   9fd9000   9ffa000 100073
... several lines omitted ...
```

Type **help vm** for more information on the command usage.

23.3.6. Displaying Open Files

To display information about open files, type the **files** command at the interactive prompt. You can use **files *pid*** to display files opened by the selected process.

Example 23.6. Displaying information about open files of the current context

```
crash> files
PID: 5591   TASK: f196d560  CPU: 2   COMMAND: "bash"
ROOT: /    CWD: /root
 FD    FILE     DENTRY    INODE    TYPE  PATH
  0  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
  1  efade5c0  eee14090  f00431d4  REG   /proc/sysrq-trigger
  2  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
 10  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
255  f734f640  eedc2c6c  eecd6048  CHR   /pts/0
```

Type **help files** for more information on the command usage.

23.3.7. Exiting the Utility

To exit the interactive prompt and terminate **crash**, type **exit** or **q**.

> Example 23.7. Exiting the crash utility
>
> ```
> crash> exit
> ~]#
> ```

23.4. Additional Resources

23.4.1. Installed Documentation

- **kdump.conf**(5) — a manual page for the **/etc/kdump.conf** configuration file containing the full documentation of available options.
- **makedumpfile**(8) — a manual page for the **makedumpfile** core collector.
- **kexec**(8) — a manual page for **kexec**.
- **crash**(8) — a manual page for the **crash** utility.
- **/usr/share/doc/kexec-tools-*version*/kexec-kdump-howto.txt** — an overview of the kdump and **kexec** installation and usage.

23.4.2. Useful Websites

https://access.redhat.com/kb/docs/DOC-6039
: The Red Hat Knowledgebase article about the **kexec** and kdump configuration.

https://access.redhat.com/kb/docs/DOC-45183
: The Red Hat Knowledgebase article about supported kdump targets.

http://people.redhat.com/anderson/
: The **crash** utility homepage.

Appendix A. Consistent Network Device Naming

Fedora 17 provides consistent network device naming for network interfaces. This feature changes the name of network interfaces on a system in order to make locating and differentiating the interfaces easier.

Traditionally, network interfaces in Linux are enumerated as `eth[0123…]`, but these names do not necessarily correspond to actual labels on the chassis. Modern server platforms with multiple network adapters can encounter non-deterministic and counter-intuitive naming of these interfaces. This affects both network adapters embedded on the motherboard (*Lan-on-Motherboard*, or *LOM*) and add-in (single and multiport) adapters.

The new naming convention assigns names to network interfaces based on their physical location, whether embedded or in PCI slots. By converting to this naming convention, system administrators will no longer have to guess at the physical location of a network port, or modify each system to rename them into some consistent order.

This feature, implemented via the **biosdevname** program, will change the name of all embedded network interfaces, PCI card network interfaces, and virtual function network interfaces from the existing `eth[0123…]` to the new naming convention as shown in *Table A.1, "The new naming convention"*.

Table A.1. The new naming convention

Device	Old Name	New Name
Embedded network interface (LOM)	`eth[0123…]`	`em[1234…]`[1]
PCI card network interface	`eth[0123…]`	`p<slot>p<ethernet port>`[2]
Virtual function	`eth[0123…]`	`p<slot>p<ethernet port>_<virtual interface>`[3]

[1] New enumeration starts at **1**.

[2] For example: `p3p4`

[3] For example: `p3p4_1`

System administrators may continue to write rules in **`/etc/udev/rules.d/70-persistent-net.rules`** to change the device names to anything desired; those will take precedence over this physical location naming convention.

A.1. Affected Systems

Consistent network device naming is enabled by default for all systems that meet the requirements in *Section A.2, "System Requirements"*.

Regardless of the type of system, Fedora guests will not have devices renamed unless the virtual machine BIOS provides the SMBIOS information outlined in *Section A.2, "System Requirements"*. Also, upgrades from prior releases that did not use this naming convention (that is, Fedora 14 and older) are unaffected, and the old naming convention will continue to be used.

A.2. System Requirements

The **biosdevname** program uses information from the system's BIOS, specifically the *type 9* (System Slot) and *type 41* (Onboard Devices Extended Information) fields contained within the SMBIOS. If the system's BIOS does not have SMBIOS version 2.6 or higher and this data, the new naming convention

will not be used. Most older hardware does not support this feature because of a lack of BIOSes with the correct SMBIOS version and field information. For BIOS or SMBIOS version information, contact your hardware vendor.

For this feature to take effect, the *biosdevname* package must also be installed. The *biosdevname* package is part of the **base** package group in Fedora 17. All install options, except for **Minimal Install**, include this package.

A.3. Enabling and Disabling the Feature

To disable the consistent network device naming on Dell systems that would normally have it on by default, pass the following option on the boot command line, both during and after installation:

```
biosdevname=0
```

To enable this feature on other system types that meet the minimum requirements (see *Section A.2, "System Requirements"*), pass the following option on the boot command line, both during and after installation:

```
biosdevname=1
```

Unless the system meets the minimum requirements, this option will be ignored and the system will boot with the traditional network interface name format.

If the **biosdevname** install option is specified, it must remain as a boot option for the lifetime of the system.

A.4. Notes for Administrators

Many system customization files can include network interface names, and thus will require updates if moving a system from the old convention to the new convention. If you use the new naming convention, you will also need to update network interface names in areas such as custom iptables rules, scripts altering irqbalance, and other similar configuration files. Also, enabling this change for installation will require modification to existing kickstart files that use device names via the **ksdevice** parameter; these kickstart files will need to be updated to use the network device's MAC address or the network device's new name.

The Fedora Project strongly recommends that you consider this feature to be an install-time choice; enabling or disabling the feature post-install, while technically possible, can be complicated and is not recommended. For those system administrators who wish to do so, on a system that meets the minimum requirements, remove the **/etc/udev/rules.d/70-persistent-net.rules** file and the **HWADDR** lines from all **/etc/sysconfig/network-scripts/ifcfg-*** files. In addition, rename those **ifcfg-*** files to use this new naming convention. The new names will be in effect after reboot. Remember to update any custom scripts, iptables rules, and service configuration files that might include network interface names.

Appendix B. RPM

The *RPM Package Manager* (RPM) is an open packaging system , which runs on Fedora as well as other Linux and UNIX systems. Red Hat, Inc. and the Fedora Project encourage other vendors to use RPM for their own products. RPM is distributed under the terms of the *GPL* (*GNU General Public License*).

The RPM Package Manager only works with packages built to work with the *RPM format*. RPM is itself provided as a pre-installed *rpm* package. For the end user, RPM makes system updates easy. Installing, uninstalling and upgrading RPM packages can be accomplished with short commands. RPM maintains a database of installed packages and their files, so you can invoke powerful queries and verifications on your system.

The RPM package format has been improved for Fedora 17. RPM packages are now compressed using the XZ lossless data compression format, which has the benefit of greater compression and less CPU usage during decompression, and support multiple strong hash algorithms, such as SHA-256, for package signing and verification.



Use Yum Instead of RPM Whenever Possible

For most package management tasks, the **Yum** package manager offers equal and often greater capabilities and utility than RPM . **Yum** also performs and tracks complicated system dependency resolution, and will complain and force system integrity checks if you use RPM as well to install and remove packages. For these reasons, it is highly recommended that you use **Yum** instead of RPM whenever possible to perform package management tasks. Refer to *Chapter 4, Yum*.

If you prefer a graphical interface, you can use the **PackageKit** GUI application, which uses **Yum** as its back end, to manage your system's packages. Refer to *Chapter 5, PackageKit* for details.



Install RPM packages with the correct architecture!

When installing a package, ensure it is compatible with your operating system and processor architecture. This can usually be determined by checking the package name. Many of the following examples show RPM packages compiled for the AMD64/Intel 64 computer architectures; thus, the RPM file name ends in **`x86_64.rpm`**.

During upgrades, RPM handles configuration files carefully, so that you never lose your customizations—something that you cannot accomplish with regular **`.tar.gz`** files.

For the developer, RPM allows you to take software source code and package it into source and binary packages for end users. This process is quite simple and is driven from a single file and optional patches that you create. This clear delineation between *pristine* sources and your patches along with build instructions eases the maintenance of the package as new versions of the software are released.



Running rpm commands must be performed as root

Because RPM makes changes to your system, you must be logged in as root to install, remove, or upgrade an RPM package.

B.1. RPM Design Goals

To understand how to use RPM, it can be helpful to understand the design goals of RPM:

Upgradability
: With RPM, you can upgrade individual components of your system without completely reinstalling. When you get a new release of an operating system based on RPM, such as Fedora, you do not need to reinstall a fresh copy of the operating system your machine (as you might need to with operating systems based on other packaging systems). RPM allows intelligent, fully-automated, in-place upgrades of your system. In addition, configuration files in packages are preserved across upgrades, so you do not lose your customizations. There are no special upgrade files needed to upgrade a package because the same RPM file is used to both install and upgrade the package on your system.

Powerful Querying
: RPM is designed to provide powerful querying options. You can perform searches on your entire database for packages or even just certain files. You can also easily find out what package a file belongs to and from where the package came. The files an RPM package contains are in a compressed archive, with a custom binary header containing useful information about the package and its contents, allowing you to query individual packages quickly and easily.

System Verification
: Another powerful RPM feature is the ability to verify packages. If you are worried that you deleted an important file for some package, you can verify the package. You are then notified of anomalies, if any—at which point you can reinstall the package, if necessary. Any configuration files that you modified are preserved during reinstallation.

Pristine Sources
: A crucial design goal was to allow the use of *pristine* software sources, as distributed by the original authors of the software. With RPM, you have the pristine sources along with any patches that were used, plus complete build instructions. This is an important advantage for several reasons. For instance, if a new version of a program is released, you do not necessarily have to start from scratch to get it to compile. You can look at the patch to see what you *might* need to do. All the compiled-in defaults, and all of the changes that were made to get the software to build properly, are easily visible using this technique.

  The goal of keeping sources pristine may seem important only for developers, but it results in higher quality software for end users, too.

B.2. Using RPM

RPM has five basic modes of operation (not counting package building): installing, uninstalling, upgrading, querying, and verifying. This section contains an overview of each mode. For complete details and options, try **`rpm --help`** or **`man rpm`**. You can also refer to *Section B.5, “Additional Resources”* for more information on RPM.

B.2.1. Finding RPM Packages

Before using any RPM packages, you must know where to find them. An Internet search returns many RPM repositories, but if you are looking for Red Hat RPM packages, they can be found at the following locations:

- The Fedora installation media contain many installable RPMs.
- The initial RPM repositories provided with the YUM package manager . Refer to *Chapter 4, Yum* for details on how to use the official Fedora package repositories.
- The active Fedora mirrors contains many installable RPMs: *http://mirrors.fedoraproject.org/publiclist/*.
- Unofficial, third-party repositories not affiliated with The Fedora Project also provide RPM packages.



Third-party repositories and package compatibility

When considering third-party repositories for use with your Fedora system, pay close attention to the repository's web site with regard to package compatibility before adding the repository as a package source. Alternate package repositories may offer different, incompatible versions of the same software, including packages already included in the Fedora repositories.

B.2.2. Installing and Upgrading

RPM packages typically have file names like **`tree-1.5.3-2.fc17.x86_64.rpm`**. The file name includes the package name (**`tree`**), version (**`1.5.3`**), release (**`2`**), operating system major version (**`fc17`**) and CPU architecture (**`x86_64`**).

You can use **`rpm`**'s **`-U`** option to:

- upgrade an existing but older package on the system to a newer version, or
- install the package even if an older version is not already installed.

That is, **`rpm -U <rpm_file>`** is able to perform the function of either *upgrading* or *installing* as is appropriate for the package.

Assuming the **`tree-1.5.3-2.fc17.x86_64.rpm`** package is in the current directory, log in as root and type the following command at a shell prompt to either upgrade or install the *tree* package as determined by **`rpm`**:

```
rpm -Uvh tree-1.5.3-2.fc17.x86_64.rpm
```



Use -Uvh for nicely-formatted RPM installs

The **-v** and **-h** options (which are combined with **-U**) cause **rpm** to print more verbose output and display a progress meter using hash signs.

If the upgrade/installation is successful, the following output is displayed:

```
Preparing...                ########################################### [100%]
   1:tree                   ########################################### [100%]
```



Always use the -i (install) option to install new kernel packages!

rpm provides two different options for installing packages: the aforementioned **-U** option (which historically stands for *upgrade*), and the **-i** option, historically standing for *install*. Because the **-U** option subsumes both install and upgrade functions, we recommend to use **rpm -Uvh** with all packages *except kernel packages*.

You should always use the **-i** option to simply *install* a new kernel package instead of upgrading it. This is because using the **-U** option to upgrade a kernel package removes the previous (older) kernel package, which could render the system unable to boot if there is a problem with the new kernel. Therefore, use the **rpm -i *<kernel_package>*** command to install a new kernel *without replacing any older kernel packages*. For more information on installing *kernel* packages, refer to *Chapter 21, Manually Upgrading the Kernel*.

The signature of a package is checked automatically when installing or upgrading a package. The signature confirms that the package was signed by an authorized party. For example, if the verification of the signature fails, an error message such as the following is displayed:

```
error: tree-1.5.2.2-4.fc17.x86_64.rpm: Header V3 RSA/SHA256 signature: BAD, key ID
d22e77f2
```

If it is a new, header-only, signature, an error message such as the following is displayed:

```
error: tree-1.5.2.2-4.fc17.x86_64.rpm: Header V3 RSA/SHA256 signature: BAD,
key ID d22e77f2
```

If you do not have the appropriate key installed to verify the signature, the message contains the word **NOKEY**:

```
warning: tree-1.5.2.2-4.fc17.x86_64.rpm: Header V3 RSA/SHA1 signature: NOKEY, key ID 57bbccba
```

Refer to *Section B.3, “Checking a Package's Signature”* for more information on checking a package's signature.

B.2.2.1. Package Already Installed

If a package of the same name and version is already installed , the following output is displayed:

```
Preparing...                ########################################### [100%]
 package tree-1.5.3-2.fc17.x86_64 is already installed
```

However, if you want to install the package anyway, you can use the **--replacepkgs** option, which tells RPM to ignore the error:

```
rpm -Uvh --replacepkgs tree-1.5.3-2.fc17.x86_64.rpm
```

This option is helpful if files installed from the RPM were deleted or if you want the original configuration files from the RPM to be installed.

B.2.2.2. Conflicting Files

If you attempt to install a package that contains a file which has already been installed by another package , the following is displayed:

```
Preparing... ##################################################
 file /usr/bin/foobar from install of foo-1.0-1.fc17.x86_64 conflicts
with file from package bar-3.1.1.fc17.x86_64
```

To make RPM ignore this error, use the **--replacefiles** option:

```
rpm -Uvh --replacefiles foo-1.0-1.fc17.x86_64.rpm
```

B.2.2.3. Unresolved Dependency

RPM packages may sometimes depend on other packages , which means that they require other packages to be installed to run properly. If you try to install a package which has an unresolved dependency, output similar to the following is displayed:

```
error: Failed dependencies:
 bar.so.3()(64bit) is needed by foo-1.0-1.fc17.x86_64
```

If you are installing a package from the Fedora installation media, such as from a CD-ROM or DVD, the dependencies may be available. Find the suggested package(s) on the Fedora installation media or on one of the active Fedora mirrors and add it to the command:

```
rpm -Uvh foo-1.0-1.fc17.x86_64.rpm    bar-3.1.1.fc17.x86_64.rpm
```

If installation of both packages is successful, output similar to the following is displayed:

```
Preparing...                ########################################### [100%]
   1:foo                    ########################################### [ 50%]
   2:bar                    ########################################### [100%]
```

You can try the **--whatprovides** option to determine which package contains the required file.

```
rpm -q --whatprovides "bar.so.3"
```

If the package that contains **bar.so.3** is in the RPM database, the name of the package is displayed:

```
bar-3.1.1.fc17.i586.rpm
```



Warning: Forcing Package Installation

Although we can *force* **rpm** to install a package that gives us a **Failed dependencies** error (using the **--nodeps** option), this is *not* recommended, and will usually result in the installed package failing to run. Installing or removing packages with **rpm --nodeps** can cause applications to misbehave and/or crash, and can cause serious package management problems or, possibly, system failure. For these reasons, it is best to heed such warnings; the package manager—whether **RPM**, **Yum** or **PackageKit**—shows us these warnings and suggests possible fixes because accounting for dependencies is critical. The **Yum** package manager can perform dependency resolution and fetch dependencies from online repositories, making it safer, easier and smarter than forcing **rpm** to carry out actions without regard to resolving dependencies.

B.2.3. Configuration File Changes

Because RPM performs intelligent upgrading of packages with configuration files , you may see one or the other of the following messages:

```
saving /etc/foo.conf as /etc/foo.conf.rpmsave
```

This message means that changes you made to the configuration file may not be *forward-compatible* with the new configuration file in the package, so RPM saved your original file and installed a new one. You should investigate the differences between the two configuration files and resolve them as soon as possible, to ensure that your system continues to function properly.

Alternatively, RPM may save the package's *new* configuration file as, for example, **foo.conf.rpmnew**, and leave the configuration file you modified untouched. You should still resolve any conflicts between your modified configuration file and the new one, usually by merging changes from the old one to the new one with a **diff** program.

If you attempt to upgrade to a package with an *older* version number (that is, if a higher version of the package is already installed), the output is similar to the following:

```
package foo-2.0-1.fc17.x86_64.rpm (which is newer than foo-1.0-1) is already installed
```

To force RPM to upgrade anyway, use the **--oldpackage** option:

```
rpm -Uvh --oldpackage foo-1.0-1.fc17.x86_64.rpm
```

B.2.4. Uninstalling

Uninstalling a package is just as simple as installing one. Type the following command at a shell prompt:

```
rpm -e foo
```

rpm -e and package name errors

Notice that we used the package *name* **foo**, not the name of the original package *file*, **foo-1.0-1.fc17.x86_64**. If you attempt to uninstall a package using the **rpm -e** command and the original full file name, you will receive a package name error.

You can encounter dependency errors when uninstalling a package if another installed package depends on the one you are trying to remove. For example:

```
rpm -e ghostscript
error: Failed dependencies:
 libgs.so.8()(64bit) is needed by (installed) libspectre-0.2.2-3.fc17.x86_64
 libgs.so.8()(64bit) is needed by (installed) foomatic-4.0.3-1.fc17.x86_64
 libijs-0.35.so()(64bit) is needed by (installed) gutenprint-5.2.4-5.fc17.x86_64
 ghostscript is needed by (installed) printer-filters-1.1-4.fc17.noarch
```

Similar to how we searched for a shared object library (i.e. a ***<library_name>.so.<number>*** file) in *Section B.2.2.3, "Unresolved Dependency"*, we can search for a 64-bit shared object library using this exact syntax (and making sure to quote the file name):

```
~]# rpm -q --whatprovides "libgs.so.8()(64bit)"
ghostscript-8.70-1.fc17.x86_64
```

Warning: Forcing Package Installation

Although we can *force* **rpm** to remove a package that gives us a **Failed dependencies** error (using the **--nodeps** option), this is *not* recommended, and may cause harm to other installed applications. Installing or removing packages with **rpm --nodeps** can cause applications to misbehave and/or crash, and can cause serious package management problems or, possibly, system failure. For these reasons, it is best to heed such warnings; the package manager—whether **RPM**, **Yum** or **PackageKit**—shows us these warnings and suggests possible fixes because accounting for dependencies is critical. The **Yum** package manager can perform dependency resolution and fetch dependencies from online repositories, making it safer, easier and smarter than forcing **rpm** to carry out actions without regard to resolving dependencies.

B.2.5. Freshening

Freshening is similar to upgrading, except that only existent packages are upgraded. Type the following command at a shell prompt:

```
rpm -Fvh foo-2.0-1.fc17.x86_64.rpm
```

RPM's freshen option checks the versions of the packages specified on the command line against the versions of packages that have already been installed on your system. When a newer version of an already-installed package is processed by RPM's freshen option, it is upgraded to the newer version.

However, RPM's freshen option does not install a package if no previously-installed package of the same name exists. This differs from RPM's upgrade option, as an upgrade *does* install packages whether or not an older version of the package was already installed.

Freshening works for single packages or package groups. If you have just downloaded a large number of different packages, and you only want to upgrade those packages that are already installed on your system, freshening does the job. Thus, you do not have to delete any unwanted packages from the group that you downloaded before using RPM.

In this case, issue the following with the **`*.rpm`** glob:

```
rpm -Fvh *.rpm
```

RPM then automatically upgrades only those packages that are already installed.

B.2.6. Querying

The RPM database stores information about all RPM packages installed in your system. It is stored in the directory **`/var/lib/rpm/`**, and is used to query what packages are installed, what versions each package is, and to calculate any changes to any files in the package since installation, among other use cases.

To query this database, use the **`-q`** option. The **`rpm -q package name`** command displays the package name, version, and release number of the installed package <*package_name*>. For example, using **`rpm -q tree`** to query installed package **`tree`** might generate the following output:

```
tree-1.5.2.2-4.fc17.x86_64
```

You can also use the following *Package Selection Options* (which is a subheading in the RPM man page: see **`man rpm`** for details) to further refine or qualify your query:

- **`-a`** — queries all currently installed packages.
- **`-f <file_name>`** — queries the RPM database for which package owns **`<file_name>`**. Specify the absolute path of the file (for example, **`rpm -qf /bin/ls`** instead of **`rpm -qf ls`**).
- **`-p <package_file>`** — queries the uninstalled package **`<package_file>`**.

There are a number of ways to specify what information to display about queried packages. The following options are used to select the type of information for which you are searching. These are called the *Package Query Options*.

- **`-i`** displays package information including name, description, release, size, build date, install date, vendor, and other miscellaneous information.
- **`-l`** displays the list of files that the package contains.
- **`-s`** displays the state of all the files in the package.
- **`-d`** displays a list of files marked as documentation (man pages, info pages, READMEs, etc.) in the package.
- **`-c`** displays a list of files marked as configuration files. These are the files you edit after installation to adapt and customize the package to your system (for example, **`sendmail.cf`**, **`passwd`**, **`inittab`**, etc.).

For options that display lists of files, add **-v** to the command to display the lists in a familiar **ls -l** format.

B.2.7. Verifying

Verifying a package compares information about files installed from a package with the same information from the original package. Among other things, verifying compares the file size, MD5 sum, permissions, type, owner, and group of each file.

The command **rpm -V** verifies a package. You can use any of the *Verify Options* listed for querying to specify the packages you wish to verify. A simple use of verifying is **rpm -V tree**, which verifies that all the files in the **tree** package are as they were when they were originally installed. For example:

- To verify a package containing a particular file:

```
rpm -Vf /usr/bin/tree
```

  In this example, **/usr/bin/tree** is the absolute path to the file used to query a package.

- To verify ALL installed packages throughout the system (which will take some time):

```
rpm -Va
```

- To verify an installed package against an RPM package file:

```
rpm -Vp tree-1.5.2.2-4.fc17.x86_64.rpm
```

  This command can be useful if you suspect that your RPM database is corrupt.

If everything verified properly, there is no output. If there are any discrepancies, they are displayed. The format of the output is a string of eight characters (a "**c**" denotes a configuration file) and then the file name. Each of the eight characters denotes the result of a comparison of one attribute of the file to the value of that attribute recorded in the RPM database. A single period (**.**) means the test passed. The following characters denote specific discrepancies:

- **5** — MD5 checksum
- **S** — file size
- **L** — symbolic link
- **T** — file modification time
- **D** — device
- **U** — user
- **G** — group
- **M** — mode (includes permissions and file type)
- **?** — unreadable file (file permission errors, for example)

If you see any output, use your best judgment to determine if you should remove the package, reinstall it, or fix the problem in another way.

B.3. Checking a Package's Signature

If you wish to verify that a package has not been corrupted or tampered with, you can examine just the md5sum by entering this command at the shell prompt: (where *<rpm_file>* is the file name of the RPM package):

```
rpm -K --nosignature <rpm_file>
```

The output **<*rpm_file*>: rsa sha1 (md5) pgp md5 OK** (specifically the *OK* part of it) indicates that the file was not corrupted during download. To see a more verbose message, replace **-K** with **-Kvv** in the command.

On the other hand, how trustworthy is the developer who created the package? If the package is *signed* with the developer's GnuPG *key*, you know that the developer really is who they say they are.

An RPM package can be signed using *Gnu Privacy Guard* (or GnuPG), to help you make certain your downloaded package is trustworthy.

GnuPG is a tool for secure communication; it is a complete and free replacement for the encryption technology of PGP, an electronic privacy program. With GnuPG, you can authenticate the validity of documents and encrypt/decrypt data to and from other recipients. GnuPG is capable of decrypting and verifying PGP 5.*x* files as well.

During installation, GnuPG is installed by default, which enables you to immediately start using it to verify any packages that you download from the Fedora Project. Before doing so, you first need to import the correct Fedora key.

B.3.1. Importing Keys

Fedora GnuPG keys are located in the **/etc/pki/rpm-gpg/** directory. To verify a Fedora Project package, first import the correct key based on your processor architecture:

```
rpm --import /etc/pki/rpm-gpg/RPM-GPG-KEY-fedora-x86_64
```

To display a list of all keys installed for RPM verification, execute the command:

```
rpm -qa gpg-pubkey*
```

For the Fedora Project key, the output states:

```
gpg-pubkey-57bbccba-4a6f97af
```

To display details about a specific key, use **rpm -qi** followed by the output from the previous command:

```
rpm -qi gpg-pubkey-57bbccba-4a6f97af
```

B.3.2. Verifying Signature of Packages

To check the GnuPG signature of an RPM file after importing the builder's GnuPG key, use the following command (replace *<rpm_file>* with the file name of the RPM package):

```
rpm -K <rpm_file>
```

If all goes well, the following message is displayed: **rsa sha1 (md5) pgp md5 OK**. This means that the signature of the package has been verified, that it is not corrupt, and is therefore safe to install and use.

For more information, including a list of currently-used Fedora Project keys and their fingerprints, refer to *http://fedoraproject.org/en/keys*.

B.4. Practical and Common Examples of RPM Usage

RPM is a useful tool for both managing your system and diagnosing and fixing problems. The best way to make sense of all its options is to look at some examples.

- Perhaps you have deleted some files by accident, but you are not sure what you deleted. To verify your entire system and see what might be missing, you could try the following command:

  ```
  rpm -Va
  ```

  If some files are missing or appear to have been corrupted, you should probably either re-install the package or uninstall and then re-install the package.

- At some point, you might see a file that you do not recognize. To find out which package owns it, enter:

  ```
  rpm -qf /usr/bin/ghostscript
  ```

  The output would look like the following:

  ```
  ghostscript-8.70-1.fc17.x86_64
  ```

- We can combine the above two examples in the following scenario. Say you are having problems with **/usr/bin/paste**. You would like to verify the package that owns that program, but you do not know which package owns **paste**. Enter the following command,

  ```
  rpm -Vf /usr/bin/paste
  ```

  and the appropriate package is verified.

- Do you want to find out more information about a particular program? You can try the following command to locate the documentation which came with the package that owns that program:

```
rpm -qdf /usr/bin/free
```

The output would be similar to the following:

```
/usr/share/doc/procps-3.2.8/BUGS
/usr/share/doc/procps-3.2.8/FAQ
/usr/share/doc/procps-3.2.8/NEWS
/usr/share/doc/procps-3.2.8/TODO
/usr/share/man/man1/free.1.gz
/usr/share/man/man1/pgrep.1.gz
/usr/share/man/man1/pkill.1.gz
/usr/share/man/man1/pmap.1.gz
/usr/share/man/man1/ps.1.gz
/usr/share/man/man1/pwdx.1.gz
/usr/share/man/man1/skill.1.gz
/usr/share/man/man1/slabtop.1.gz
/usr/share/man/man1/snice.1.gz
/usr/share/man/man1/tload.1.gz
/usr/share/man/man1/top.1.gz
/usr/share/man/man1/uptime.1.gz
/usr/share/man/man1/w.1.gz
/usr/share/man/man1/watch.1.gz
/usr/share/man/man5/sysctl.conf.5.gz
/usr/share/man/man8/sysctl.8.gz
/usr/share/man/man8/vmstat.8.gz
```

- You may find a new RPM, but you do not know what it does. To find information about it, use the following command:

```
rpm -qip crontabs-1.10-31.fc17.noarch.rpm
```

The output would be similar to the following:

```
Name        : crontabs                     Relocations: (not relocatable)
Size        : 2486                            License: Public Domain and GPLv2
Signature   : RSA/SHA1, Tue 11 Aug 2009 01:11:19 PM CEST, Key ID 9d1cc34857bbccba
Packager    : Fedora Project
Summary     : Root crontab files used to schedule the execution of programs
Description :
The crontabs package contains root crontab files and directories.
You will need to install cron daemon to run the jobs from the crontabs.
The cron daemon such as cronie or fcron checks the crontab files to
see when particular commands are scheduled to be executed.  If commands
are scheduled, it executes them.
Crontabs handles a basic system function, so it should be installed on
your system.
```

- Perhaps you now want to see what files the **crontabs** RPM package installs. You would enter the following:

```
```

```
rpm -qlp crontabs-1.10-31.fc17.noarch.rpm
```

The output is similar to the following:

```
/etc/cron.daily
/etc/cron.hourly
/etc/cron.monthly
/etc/cron.weekly
/etc/crontab
/usr/bin/run-parts
/usr/share/man/man4/crontabs.4.gz
```

These are just a few examples. As you use RPM, you may find more uses for it.

B.5. Additional Resources

RPM is an extremely complex utility with many options and methods for querying, installing, upgrading, and removing packages. Refer to the following resources to learn more about RPM.

B.5.1. Installed Documentation

- **`rpm --help`** — This command displays a quick reference of RPM parameters.
- **`man rpm`** — The RPM man page gives more detail about RPM parameters than the **`rpm --help`** command.

B.5.2. Useful Websites

- The RPM website — *http://www.rpm.org/*
- The RPM mailing list can be subscribed to, and its archives read from, here — *https://lists.rpm.org/mailman/listinfo/rpm-list*[1]

B.5.3. Related Books

Maximum RPM — *http://www.rpm.org/max-rpm/*

The *Maximum RPM* book, which you can read online, covers everything from general RPM usage to building your own RPMs to programming with rpmlib.

[1] http://www.redhat.com/mailman/listinfo/rpm-list/

Appendix C. The X Window System

While the heart of Fedora is the kernel, for many users, the face of the operating system is the graphical environment provided by the *X Window System*, also called *X*.

Other windowing environments have existed in the UNIX world, including some that predate the release of the X Window System in June 1984. Nonetheless, X has been the default graphical environment for most UNIX-like operating systems, including Fedora, for many years.

The graphical environment for Fedora is supplied by the *X.Org Foundation*, an open source organization created to manage development and strategy for the X Window System and related technologies. X.Org is a large-scale, rapid-developing project with hundreds of developers around the world. It features a wide degree of support for a variety of hardware devices and architectures, and runs on myriad operating systems and platforms.

The X Window System uses a client-server architecture. Its main purpose is to provide network transparent window system, which runs on a wide range of computing and graphics machines. The *X server* (the **Xorg** binary) listens for connections from *X client* applications via a network or local loopback interface. The server communicates with the hardware, such as the video card, monitor, keyboard, and mouse. X client applications exist in the user space, creating a *graphical user interface* (*GUI*) for the user and passing user requests to the X server.

C.1. The X Server

Fedora 17 uses X server version, which includes several video drivers, EXA, and platform support enhancements over the previous release, among others. In addition, this release includes several automatic configuration features for the X server, as well as the generic input driver, `evdev`, that supports all input devices that the kernel knows about, including most mice and keyboards.

X11R7.1 was the first release to take specific advantage of the modularization of the X Window System. With it, X is split into logically distinct modules, which make it easier for open source developers to contribute code to the system.

In the current release, all libraries, headers, and binaries live under the **/usr/** directory. The **/etc/X11/** directory contains configuration files for X client and server applications. This includes configuration files for the X server itself, the X display managers, and many other base components.

The configuration file for the newer Fontconfig-based font architecture is still **/etc/fonts/fonts.conf**. For more information on configuring and adding fonts, refer to *Section C.4, “Fonts”*.

Because the X server performs advanced tasks on a wide array of hardware, it requires detailed information about the hardware it works on. The X server is able to automatically detect most of the hardware that it runs on and configure itself accordingly. Alternatively, hardware can be manually specified in configuration files.

The Fedora system installer, Anaconda, installs and configures X automatically, unless the X packages are not selected for installation. If there are any changes to the monitor, video card or other devices managed by the X server, most of the time, X detects and reconfigures these changes automatically. In rare cases, X must be reconfigured manually.

C.2. Desktop Environments and Window Managers

Once an X server is running, X client applications can connect to it and create a GUI for the user. A range of GUIs are available with Fedora, from the rudimentary *Tab Window Manager* (twm) to the

highly developed and interactive desktop environment (such as *GNOME* or *KDE*) that most Fedora users are familiar with.

To create the latter, more comprehensive GUI, two main classes of X client application must connect to the X server: a *window manager* and a *desktop environment*.

C.2.1. Desktop Environments

A desktop environment integrates various X clients to create a common graphical user environment and a development platform.

Desktop environments have advanced features allowing X clients and other running processes to communicate with one another, while also allowing all applications written to work in that environment to perform advanced tasks, such as drag-and-drop operations.

Fedora provides two desktop environments:

- *GNOME* — The default desktop environment for Fedora based on the GTK+ 2 graphical toolkit.
- *KDE* — An alternative desktop environment based on the Qt 4 graphical toolkit.

Both GNOME and KDE have advanced-productivity applications, such as word processors, spreadsheets, and Web browsers; both also provide tools to customize the look and feel of the GUI. Additionally, if both the GTK+ 2 and the Qt libraries are present, KDE applications can run in GNOME and vice versa.

C.2.2. Window Managers

Window managers are X client programs which are either part of a desktop environment or, in some cases, stand-alone. Their primary purpose is to control the way graphical windows are positioned, resized, or moved. Window managers also control title bars, window focus behavior, and user-specified key and mouse button bindings.

The Fedora repositories provide five different window managers:

`metacity`
The *Metacity* window manager is the default window manager for GNOME. It is a simple and efficient window manager which supports custom themes. This window manager is automatically pulled in as a dependency when the GNOME desktop is installed.

`kwin`
The *KWin* window manager is the default window manager for KDE. It is an efficient window manager which supports custom themes. This window manager is automatically pulled in as a dependency when the KDE desktop is installed.

`compiz`
The *Compiz* compositing window manager is based on OpenGL and can use 3D graphics hardware to create fast compositing desktop effects for window management. Advanced features, such as a cube workspace, are implemented as loadable plug-ins. To run this window manager, you need to install the **`compiz`** package.

`mwm`
The *Motif Window Manager* (**`mwm`**) is a basic, stand-alone window manager. Since it is designed to be stand-alone, it should not be used in conjunction with GNOME or KDE. To run this window manager, you need to install the **`openmotif`** package.

twm
: The minimalist *Tab Window Manager* (**twm**), which provides the most basic tool set among the available window managers, can be used either as a stand-alone or with a desktop environment. To run this window manager, you need to install the **xorg-x11-twm** package.

C.3. X Server Configuration Files

The X server is a single binary executable **/usr/bin/Xorg**; a symbolic link **X** pointing to this file is also provided. Associated configuration files are stored in the **/etc/X11/** and **/usr/share/X11/** directories.

The X Window System supports two different configuration schemes. Configuration files in the **xorg.conf.d** directory contain preconfigured settings from vendors and from distribution, and these files should not be edited by hand. Configuration in the **xorg.conf** file, on the other hand, is done completely by hand but is not necessary in most scenarios.



When do you need the xorg.conf file?

All necessary parameters for a display and peripherals are auto-detected and configured during installation. The configuration file for the X server, **/etc/X11/xorg.conf**, that was necessary in previous releases, is not supplied with the current release of the X Window System. It can still be useful to create the file manually to configure new hardware, to set up an environment with multiple video cards, or for debugging purposes.

The **/usr/lib/xorg/modules/** (or **/usr/lib64/xorg/modules/**) directory contains X server modules that can be loaded dynamically at runtime. By default, only some modules in **/usr/lib/xorg/modules/** are automatically loaded by the X server.

When Fedora 17 is installed, the configuration files for X are created using information gathered about the system hardware during the installation process by the HAL (Hardware Abstraction Layer) configuration back end. Whenever the X server is started, it asks HAL for the list of input devices and adds each of them with their respective driver. Whenever a new input device is plugged in, or an existing input device is removed, HAL notifies the X server about the change. Because of this notification system, devices using the `mouse`, `kbd`, or `vmmouse` driver configured in the **xorg.conf** file are, by default, ignored by the X server. Refer to *Section C.3.3.3, "The **ServerFlags** section"* for further details. Additional configuration is provided in the **/etc/X11/xorg.conf.d/** directory and it can override or augment any configuration that has been obtained through HAL.

C.3.1. The Structure of the Configuration

The format of the X configuration files is comprised of many different sections which address specific aspects of the system hardware. Each section begins with a **Section "*section-name*"** line, where "*section-name*" is the title for the section, and ends with an **EndSection** line. Each section contains lines that include option names and one or more option values. Some of these are sometimes enclosed in double quotes (**"**).

Some options within the **/etc/X11/xorg.conf** file accept a boolean switch which turns the feature on or off. The acceptable values are:

- **1**, **on**, **true**, or **yes** — Turns the option on.

- **0**, **off**, **false**, or **no** — Turns the option off.

The following shows a typical configuration file for the keyboard. Lines beginning with a hash sign (#) are not read by the X server and are used for human-readable comments.

```
# This file is autogenerated by system-setup-keyboard. Any
# modifications will be lost.

Section "InputClass"
  Identifier  "system-setup-keyboard"
  MatchIsKeyboard "on"
  Option    "XkbModel"  "pc105"
  Option    "XkbLayout" "cz,us"
# Option    "XkbVariant"  "(null)"
  Option    "XkbOptions"  "terminate:ctrl_alt_bksp,grp:shifts_toggle,grp_led:scroll"
EndSection
```

C.3.2. The xorg.conf.d Directory

The X server supports two configuration directories. The **/usr/share/X11/xorg.conf.d/** provides separate configuration files from vendors or third-party packages; changes to files in this directory may be overwritten by settings specified in the **/etc/X11/xorg.conf** file. The **/etc/X11/xorg.conf.d/** directory stores user-specific configuration.

Files with the suffix **.conf** in configuration directories are parsed by the X server upon startup and are treated like part of the traditional **xorg.conf** configuration file. These files may contain one or more sections; for a description of the options in a section and the general layout of the configuration file, refer to *Section C.3.3, "The **xorg.conf** File"* or to the `xorg.conf(5)` man page. The X server essentially treats the collection of configuration files as one big file with entries from **xorg.conf** at the end. Users are encouraged to put custom configuration into **/etc/xorg.conf** and leave the directory for configuration snippets provided by the distribution.

C.3.3. The xorg.conf File

In previous releases of the X Window System, **/etc/X11/xorg.conf** file was used to store initial setup for X. When a change occurred with the monitor, video card or other device managed by the X server, the file needed to be edited manually. In Fedora, there is rarely a need to manually create and edit the **/etc/X11/xorg.conf** file. Nevertheless, it is still useful to understand various sections and optional parameters available, especially when troubleshooting or setting up unusual hardware configuration.

In the following, some important sections are described in the order in which they appear in a typical **/etc/X11/xorg.conf** file. More detailed information about the X server configuration file can be found in the **xorg.conf(5)** man page. This section is mostly intended for advanced users as most configuration options described below are not needed in typical configuration scenarios.

C.3.3.1. The InputClass section

InputClass is a new type of configuration section that does not apply to a single device but rather to a class of devices, including hot-plugged devices. An **InputClass** section's scope is limited by the matches specified; in order to apply to an input device, all matches must apply to the device as seen in the example below:

```
Section "InputClass"
```

```
    Identifier      "touchpad catchall"
    MatchIsTouchpad "on"
    Driver           "synaptics"
EndSection
```

If this snippet is present in an **xorg.conf** file or an **xorg.conf.d** directory, any touchpad present in the system is assigned the `synaptics` driver.



Alphanumeric sorting in xorg.conf.d

Note that due to alphanumeric sorting of configuration files in the **xorg.conf.d** directory, the **Driver** setting in the example above overwrites previously set driver options. The more generic the class, the earlier it should be listed.

The match options specify which devices a section may apply to. To match a device, all match options must correspond. The following options are commonly used in the **InputClass** section:

- **MatchIsPointer**, **MatchIsKeyboard**, **MatchIsTouchpad**, **MatchIsTouchscreen**, **MatchIsJoystick** — boolean options to specify a type of a device.
- **MatchProduct "*product_name*"** — this option matches if the *product_name* substring occurs in the product name of the device.
- **MatchVendor "*vendor_name*"** — this option matches if the *vendor_name* substring occurs in the vendor name of the device.
- **MatchDevicePath "*/path/to/device*"** — this option matches any device if its device path corresponds to the patterns given in the "*/path/to/device*" template, for example **/dev/input/event***. Refer to the **fnmatch(3)** man page for further details.
- **MatchTag "*tag_pattern*"** — this option matches if at least one tag assigned by the HAL configuration back end matches the *tag_pattern* pattern.

A configuration file may have multiple **InputClass** sections. These sections are optional and are used to configure a class of input devices as they are automatically added. An input device can match more than one **InputClass** section. When arranging these sections, it is recommended to put generic matches above specific ones because each input class can override settings from a previous one if an overlap occurs.

C.3.3.2. The InputDevice section

Each **InputDevice** section configures one input device for the X server. Previously, systems typically had at least one **InputDevice** section for the keyboard, and most mouse settings were automatically detected.

With Fedora 17, no **InputDevice** configuration is needed for most setups, and the *xorg-x11-drv-** input driver packages provide the automatic configuration through HAL. The default driver for both keyboards and mice is **evdev**.

The following example shows a typical **InputDevice** section for a keyboard:

```
Section "InputDevice"
```

```
  Identifier "Keyboard0"
  Driver "kbd"
  Option "XkbModel" "pc105"
  Option "XkbLayout" "us"
EndSection
```

The following entries are commonly used in the **InputDevice** section:

- **Identifier** — Specifies a unique name for this **InputDevice** section. This is a required entry.
- **Driver** — Specifies the name of the device driver X must load for the device. If the **AutoAddDevices** option is enabled (which is the default setting), any input device section with **Driver "mouse"** or **Driver "kbd"** will be ignored. This is necessary due to conflicts between the legacy mouse and keyboard drivers and the new **evdev** generic driver. Instead, the server will use the information from the back end for any input devices. Any custom input device configuration in the **xorg.conf** should be moved to the back end. In most cases, the back end will be HAL and the configuration location will be the **/etc/X11/xorg.conf.d** directory.
- **Option** — Specifies necessary options pertaining to the device.

  A mouse may also be specified to override any auto-detected values for the device. The following options are typically included when adding a mouse in the **xorg.conf** file:

  - **Protocol** — Specifies the protocol used by the mouse, such as **IMPS/2**.
  - **Device** — Specifies the location of the physical device.
  - **Emulate3Buttons** — Specifies whether to allow a two-button mouse to act like a three-button mouse when both mouse buttons are pressed simultaneously.

  Consult the **xorg.conf(5)** man page for a complete list of valid options for this section.

C.3.3.3. The ServerFlags section

The optional **ServerFlags** section contains miscellaneous global X server settings. Any settings in this section may be overridden by options placed in the **ServerLayout** section (refer to *Section C.3.3.4, "**ServerLayout**"* for details).

Each entry within the **ServerFlags** section occupies a single line and begins with the term **Option** followed by an option enclosed in double quotation marks (**"**).

The following is a sample **ServerFlags** section:

```
Section "ServerFlags"
  Option "DontZap" "true"
EndSection
```

The following lists some of the most useful options:

- **"DontZap" "*boolean*"** — When the value of <*boolean*> is set to **true**, this setting prevents the use of the **Ctrl**+**Alt**+**Backspace** key combination to immediately terminate the X server.



X keyboard extension

Even if this option is enabled, the key combination still must be configured in the X Keyboard Extension (XKB) map before it can be used. One way how to add the key combination to the map is to run the following command:

```
setxkbmap -option "terminate:ctrl_alt_bksp"
```

- **"DontZoom" "*boolean*"** — When the value of <*boolean*> is set to **true**, this setting prevents cycling through configured video resolutions using the **Ctrl**+**Alt**+**Keypad-Plus** and **Ctrl**+**Alt**+**Keypad-Minus** key combinations.
- **"AutoAddDevices" "*boolean*"** — When the value of <*boolean*> is set to **false**, the server will not hot plug input devices and instead rely solely on devices configured in the **xorg.conf** file. Refer to *Section C.3.3.2, "The **InputDevice** section"* for more information concerning input devices. This option is enabled by default and HAL (hardware abstraction layer) is used as a back end for device discovery.

C.3.3.4. ServerLayout

The **ServerLayout** section binds together the input and output devices controlled by the X server. At a minimum, this section must specify one input device and one output device. By default, a monitor (output device) and a keyboard (input device) are specified.

The following example shows a typical **ServerLayout** section:

```
Section "ServerLayout"
  Identifier "Default Layout"
  Screen 0 "Screen0" 0 0
  InputDevice "Mouse0" "CorePointer"
  InputDevice "Keyboard0" "CoreKeyboard"
EndSection
```

The following entries are commonly used in the **ServerLayout** section:

- **Identifier** — Specifies a unique name for this **ServerLayout** section.
- **Screen** — Specifies the name of a **Screen** section to be used with the X server. More than one **Screen** option may be present.

  The following is an example of a typical **Screen** entry:

  ```
  Screen 0 "Screen0" 0 0
  ```

  The first number in this example **Screen** entry (**0**) indicates that the first monitor connector, or *head* on the video card, uses the configuration specified in the **Screen** section with the identifier **"Screen0"**.

  An example of a **Screen** section with the identifier **"Screen0"** can be found in *Section C.3.3.8, "The **Screen** section"*.

If the video card has more than one head, another **Screen** entry with a different number and a different **Screen** section identifier is necessary.

The numbers to the right of **"Screen0"** give the absolute X and Y coordinates for the upper left corner of the screen (**0 0** by default).

- **InputDevice** — Specifies the name of an **InputDevice** section to be used with the X server.

  It is advisable that there be at least two **InputDevice** entries: one for the default mouse and one for the default keyboard. The options **CorePointer** and **CoreKeyboard** indicate that these are the primary mouse and keyboard. If the **AutoAddDevices** option is enabled, this entry needs not to be specified in the **ServerLayout** section. If the **AutoAddDevices** option is disabled, both mouse and keyboard are auto-detected with the default values.

- **Option "*option-name*"** — An optional entry which specifies extra parameters for the section. Any options listed here override those listed in the **ServerFlags** section.

  Replace <*option-name*> with a valid option listed for this section in the **xorg.conf(5)** man page.

It is possible to put more than one **ServerLayout** section in the **/etc/X11/xorg.conf** file. By default, the server only reads the first one it encounters, however. If there is an alternative **ServerLayout** section, it can be specified as a command line argument when starting an X session; as in the **Xorg -layout <layoutname>** command.

C.3.3.5. The Files section

The **Files** section sets paths for services vital to the X server, such as the font path. This is an optional section, as these paths are normally detected automatically. This section can be used to override automatically detected values.

The following example shows a typical **Files** section:

```
Section "Files"
  RgbPath "/usr/share/X11/rgb.txt"
  FontPath "unix/:7100"
EndSection
```

The following entries are commonly used in the **Files** section:

- **ModulePath** — An optional parameter which specifies alternate directories which store X server modules.

C.3.3.6. The Monitor section

Each **Monitor** section configures one type of monitor used by the system. This is an optional entry as most monitors are now detected automatically.

This example shows a typical **Monitor** section for a monitor:

```
Section "Monitor"
  Identifier "Monitor0"
  VendorName "Monitor Vendor"
  ModelName "DDC Probed Monitor - ViewSonic G773-2"
  DisplaySize 320 240
```

```
  HorizSync 30.0 - 70.0
  VertRefresh 50.0 - 180.0
EndSection
```

The following entries are commonly used in the **Monitor** section:

- **Identifier** — Specifies a unique name for this **Monitor** section. This is a required entry.
- **VendorName** — An optional parameter which specifies the vendor of the monitor.
- **ModelName** — An optional parameter which specifies the monitor's model name.
- **DisplaySize** — An optional parameter which specifies, in millimeters, the physical size of the monitor's picture area.
- **HorizSync** — Specifies the range of horizontal sync frequencies compatible with the monitor, in kHz. These values help the X server determine the validity of built-in or specified **Modeline** entries for the monitor.
- **VertRefresh** — Specifies the range of vertical refresh frequencies supported by the monitor, in kHz. These values help the X server determine the validity of built-in or specified **Modeline** entries for the monitor.
- **Modeline** — An optional parameter which specifies additional video modes for the monitor at particular resolutions, with certain horizontal sync and vertical refresh resolutions. Refer to the **xorg.conf(5)** man page for a more detailed explanation of **Modeline** entries.
- **Option "*option-name*"** — An optional entry which specifies extra parameters for the section. Replace <*option-name*> with a valid option listed for this section in the **xorg.conf(5)** man page.

C.3.3.7. The Device section

Each **Device** section configures one video card on the system. While one **Device** section is the minimum, additional instances may occur for each video card installed on the machine.

The following example shows a typical **Device** section for a video card:

```
Section "Device"
  Identifier "Videocard0"
  Driver "mga"
  VendorName "Videocard vendor"
  BoardName "Matrox Millennium G200"
  VideoRam 8192
  Option "dpms"
EndSection
```

The following entries are commonly used in the **Device** section:

- **Identifier** — Specifies a unique name for this **Device** section. This is a required entry.
- **Driver** — Specifies which driver the X server must load to utilize the video card. A list of drivers can be found in **/usr/share/hwdata/videodrivers**, which is installed with the *hwdata* package.
- **VendorName** — An optional parameter which specifies the vendor of the video card.
- **BoardName** — An optional parameter which specifies the name of the video card.

- **VideoRam** — An optional parameter which specifies the amount of RAM available on the video card, in kilobytes. This setting is only necessary for video cards the X server cannot probe to detect the amount of video RAM.
- **BusID** — An entry which specifies the bus location of the video card. On systems with only one video card a **BusID** entry is optional and may not even be present in the default **/etc/X11/xorg.conf** file. On systems with more than one video card, however, a **BusID** entry is required.
- **Screen** — An optional entry which specifies which monitor connector or head on the video card the **Device** section configures. This option is only useful for video cards with multiple heads.

  If multiple monitors are connected to different heads on the same video card, separate **Device** sections must exist and each of these sections must have a different **Screen** value.

  Values for the **Screen** entry must be an integer. The first head on the video card has a value of **0**. The value for each additional head increments this value by one.
- **Option "*option-name*"** — An optional entry which specifies extra parameters for the section. Replace *<option-name>* with a valid option listed for this section in the **xorg.conf(5)** man page.

  One of the more common options is **"dpms"** (for Display Power Management Signaling, a VESA standard), which activates the Service Star energy compliance setting for the monitor.

C.3.3.8. The Screen section

Each **Screen** section binds one video card (or video card head) to one monitor by referencing the **Device** section and the **Monitor** section for each. While one **Screen** section is the minimum, additional instances may occur for each video card and monitor combination present on the machine.

The following example shows a typical **Screen** section:

```
Section "Screen"
  Identifier "Screen0"
  Device "Videocard0"
  Monitor "Monitor0"
  DefaultDepth 16

  SubSection "Display"
    Depth 24
    Modes "1280x1024" "1280x960" "1152x864" "1024x768" "800x600" "640x480"
  EndSubSection

  SubSection "Display"
    Depth 16
    Modes "1152x864" "1024x768" "800x600" "640x480"
  EndSubSection
EndSection
```

The following entries are commonly used in the **Screen** section:

- **Identifier** — Specifies a unique name for this **Screen** section. This is a required entry.
- **Device** — Specifies the unique name of a **Device** section. This is a required entry.
- **Monitor** — Specifies the unique name of a **Monitor** section. This is only required if a specific **Monitor** section is defined in the **xorg.conf** file. Normally, monitors are detected automatically.

- **DefaultDepth** — Specifies the default color depth in bits. In the previous example, **16** (which provides thousands of colors) is the default. Only one **DefaultDepth** entry is permitted, although this can be overridden with the Xorg command line option **-depth <*n*>**, where **<*n*>** is any additional depth specified.
- **SubSection "Display"** — Specifies the screen modes available at a particular color depth. The **Screen** section can have multiple **Display** subsections, which are entirely optional since screen modes are detected automatically.

  This subsection is normally used to override auto-detected modes.
- **Option "*option-name*"** — An optional entry which specifies extra parameters for the section. Replace <*option-name*> with a valid option listed for this section in the **xorg.conf(5)** man page.

C.3.3.9. The DRI section

The optional **DRI** section specifies parameters for the *Direct Rendering Infrastructure* (*DRI*). DRI is an interface which allows 3D software applications to take advantage of 3D hardware acceleration capabilities built into most modern video hardware. In addition, DRI can improve 2D performance via hardware acceleration, if supported by the video card driver.

This section is rarely used, as the DRI Group and Mode are automatically initialized to default values. If a different Group or Mode is needed, then adding this section to the **xorg.conf** file will override the default values.

The following example shows a typical **DRI** section:

```
Section "DRI"
  Group 0
  Mode 0666
EndSection
```

Since different video cards use DRI in different ways, do not add to this section without first referring to *http://dri.freedesktop.org/wiki/*.

C.4. Fonts

Fedora uses *Fontconfig* subsystem to manage and display fonts under the X Window System. It simplifies font management and provides advanced display features, such as anti-aliasing. This system is used automatically for applications programmed using the **Qt 3** or **GTK+ 2** graphical toolkits, or their newer versions.

The Fontconfig font subsystem allows applications to directly access fonts on the system and use the *X FreeType interface library* (*Xft*) or other rendering mechanisms to render Fontconfig fonts with advanced features such as anti-aliasing. Graphical applications can use the Xft library with Fontconfig to draw text to the screen.



Font configuration

Fontconfig uses the **/etc/fonts/fonts.conf** configuration file, which should not be edited by hand.



Fonts group

Any system where the user expects to run remote X applications needs to have the `fonts` group installed. This can be done by selecting the group in the installer, and also by running the **yum groupinstall fonts** command after installation.

C.4.1. Adding Fonts to Fontconfig

Adding new fonts to the Fontconfig subsystem is a straightforward process:

1. To add fonts for an individual user, copy the new fonts into the **.fonts/** directory in the user's home directory.

   To add fonts system-wide, copy the new fonts into the **/usr/share/fonts/** directory. It is a good idea to create a new subdirectory, such as **local/** or similar, to help distinguish between user-installed and default fonts.

2. Run the **fc-cache** command as root to update the font information cache:

   ```
   fc-cache <path-to-font-directory>
   ```

   In this command, replace *<path-to-font-directory>* with the directory containing the new fonts (either **/usr/share/fonts/local/** or **/home/<user>/.fonts/**).



Interactive font installation

Individual users may also install fonts interactively, by typing **fonts:///** into the **Nautilus** address bar, and dragging the new font files there.

C.5. Runlevels and X

In most cases, the Fedora installer configures a machine to boot into a graphical login environment, known as *runlevel 5*. It is possible, however, to boot into a text-only multi-user mode called *runlevel 3* and begin an X session from there.

The following subsections review how X starts up in both runlevel 3 and runlevel 5.

C.5.1. Runlevel 3

When in runlevel 3, the best way to start an X session is to log in and type **startx**. The **startx** command is a front-end to the **xinit** command, which launches the X server (**Xorg**) and connects X client applications to it. Because the user is already logged into the system at runlevel 3, **startx** does not launch a display manager or authenticate users. Refer to *Section C.5.2, "Runlevel 5"* for more information about display managers.

1. When the **startx** command is executed, it searches for the **.xinitrc** file in the user's home directory to define the desktop environment and possibly other X client applications to run. If no **.xinitrc** file is present, it uses the system default **/etc/X11/xinit/xinitrc** file instead.

2. The default **xinitrc** script then searches for user-defined files and default system files, including **.Xresources**, **.Xmodmap**, and **.Xkbmap** in the user's home directory, and **Xresources**, **Xmodmap**, and **Xkbmap** in the **/etc/X11/** directory. The **Xmodmap** and **Xkbmap** files, if they exist, are used by the **xmodmap** utility to configure the keyboard. The **Xresources** file is read to assign specific preference values to applications.

3. After setting the above options, the **xinitrc** script executes all scripts located in the **/etc/X11/xinit/xinitrc.d/** directory. One important script in this directory is **xinput.sh**, which configures settings such as the default language.

4. The **xinitrc** script attempts to execute **.Xclients** in the user's home directory and turns to **/etc/X11/xinit/Xclients** if it cannot be found. The purpose of the **Xclients** file is to start the desktop environment or, possibly, just a basic window manager. The **.Xclients** script in the user's home directory starts the user-specified desktop environment in the **.Xclients-default** file. If **.Xclients** does not exist in the user's home directory, the standard **/etc/X11/xinit/Xclients** script attempts to start another desktop environment, trying GNOME first, then KDE, followed by **twm**.

When in runlevel 3, the user is returned to a text mode user session after ending an X session.

C.5.2. Runlevel 5

When the system boots into runlevel 5, a special X client application called a *display manager* is launched. A user must authenticate using the display manager before any desktop environment or window managers are launched.

Depending on the desktop environments installed on the system, three different display managers are available to handle user authentication.

- **GDM** (GNOME Display Manager) — The default display manager for Fedora. **GNOME** allows the user to configure language settings, shutdown, restart or log in to the system.
- **KDM** — KDE's display manager which allows the user to shutdown, restart or log in to the system.
- **xdm** (X Window Display Manager) — A very basic display manager which only lets the user log in to the system.

When booting into runlevel 5, the **/etc/X11/prefdm** script determines the preferred display manager by referencing the **/etc/sysconfig/desktop** file. A list of options for this file is available in this file:

```
/usr/share/doc/initscripts-<version-number>/sysconfig.txt
```

where <*version-number*> is the version number of the **initscripts** package.

Each of the display managers reference the **/etc/X11/xdm/Xsetup_0** file to set up the login screen. Once the user logs into the system, the **/etc/X11/xdm/GiveConsole** script runs to assign ownership of the console to the user. Then, the **/etc/X11/xdm/Xsession** script runs to accomplish many of the tasks normally performed by the **xinitrc** script when starting X from runlevel 3, including setting system and user resources, as well as running the scripts in the **/etc/X11/xinit/xinitrc.d/** directory.

Users can specify which desktop environment they want to use when they authenticate using the **GNOME** or **KDE** display managers by selecting it from the **Sessions** menu item accessed by selecting **System**□□□ **Preferences**□□□ **More Preferences**□□□ **Sessions**. If the desktop environment is not specified in the display manager, the **/etc/X11/xdm/Xsession** script checks the **.xsession** and **.Xclients** files in the user's home directory to decide which desktop environment to load. As a last resort, the **/etc/X11/xinit/Xclients** file is used to select a desktop environment or window manager to use in the same way as runlevel 3.

When the user finishes an X session on the default display (**:0**) and logs out, the **/etc/X11/xdm/TakeConsole** script runs and reassigns ownership of the console to the root user. The original display manager, which continues running after the user logged in, takes control by spawning a new display manager. This restarts the X server, displays a new login window, and starts the entire process over again.

The user is returned to the display manager after logging out of X from runlevel 5.

For more information on how display managers control user authentication, refer to the **/usr/share/doc/gdm-<*version-number*>/README** , where <*version-number*> is the version number for the **gdm** package installed, or the **xdm** man page.

C.6. Additional Resources

There is a large amount of detailed information available about the X server, the clients that connect to it, and the assorted desktop environments and window managers.

C.6.1. Installed Documentation

- **/usr/share/X11/doc/** — contains detailed documentation on the X Window System architecture, as well as how to get additional information about the Xorg project as a new user.
- **/usr/share/doc/gdm-<*version-number*>/README** — contains information on how display managers control user authentication.
- **man xorg.conf** — Contains information about the **xorg.conf** configuration files, including the meaning and syntax for the different sections within the files.
- **man Xorg** — Describes the **Xorg** display server.

C.6.2. Useful Websites

- *http://www.X.org/* — Home page of the X.Org Foundation, which produces major releases of the X Window System bundled with Fedora to control the necessary hardware and provide a GUI environment.

- *http://dri.sourceforge.net/* — Home page of the DRI (Direct Rendering Infrastructure) project. The DRI is the core hardware 3D acceleration component of X.
- *http://www.gnome.org/*[1] — Home of the GNOME project.
- *http://www.kde.org/*[2] — Home of the KDE desktop environment.

[1] http://www.gnome.org
[2] http://www.kde.org

Appendix D. The sysconfig Directory

This appendix outlines some of the files and directories found in the **/etc/sysconfig/** directory, their function, and their contents. The information in this appendix is not intended to be complete, as many of these files have a variety of options that are only used in very specific or rare circumstances.



The content of the /etc/sysconfig/ directory

The actual content of your **/etc/sysconfig/** directory depends on the programs you have installed on your machine. To find the name of the package the configuration file belongs to, type the following at a shell prompt:

```
~]$ yum provides /etc/sysconfig/filename
```

Refer to *Section 4.2.4, "Installing Packages"* for more information on how to install new packages in Fedora.

D.1. Files in the /etc/sysconfig/ Directory

The following sections offer descriptions of files normally found in the **/etc/sysconfig/** directory.

D.1.1. /etc/sysconfig/arpwatch

The **/etc/sysconfig/arpwatch** file is used to pass arguments to the **arpwatch** daemon at boot time. By default, it contains the following option:

OPTIONS=*value*
Additional options to be passed to the **arpwatch** daemon. For example:

```
OPTIONS="-u arpwatch -e root -s 'root (Arpwatch)'"
```

D.1.2. /etc/sysconfig/authconfig

The **/etc/sysconfig/authconfig** file sets the authorization to be used on the host. By default, it contains the following options:

USEMKHOMEDIR=*boolean*
A boolean to enable (**yes**) or disable (**no**) creating a home directory for a user on the first login. For example:

```
USEMKHOMEDIR=no
```

USEPAMACCESS=*boolean*
A boolean to enable (**yes**) or disable (**no**) the PAM authentication. For example:

```
USEPAMACCESS=no
```

USESSSDAUTH=*boolean*

A boolean to enable (**yes**) or disable (**no**) the SSSD authentication. For example:

```
USESSSDAUTH=no
```

USESHADOW=*boolean*

A boolean to enable (**yes**) or disable (**no**) shadow passwords. For example:

```
USESHADOW=yes
```

USEWINBIND=*boolean*

A boolean to enable (**yes**) or disable (**no**) using Winbind for user account configuration. For example:

```
USEWINBIND=no
```

USEDB=*boolean*

A boolean to enable (**yes**) or disable (**no**) the FAS authentication. For example:

```
USEDB=no
```

USEFPRINTD=*boolean*

A boolean to enable (**yes**) or disable (**no**) the fingerprint authentication. For example:

```
USEFPRINTD=yes
```

FORCESMARTCARD=*boolean*

A boolean to enable (**yes**) or disable (**no**) enforcing the smart card authentication. For example:

```
FORCESMARTCARD=no
```

PASSWDALGORITHM=*value*

The password algorithm. The *value* can be **bigcrypt**, **descrypt**, **md5**, **sha256**, or **sha512**. For example:

```
PASSWDALGORITHM=sha512
```

USELDAPAUTH=*boolean*

A boolean to enable (**yes**) or disable (**no**) the LDAP authentication. For example:

```
USELDAPAUTH=no
```

USELOCAUTHORIZE=*boolean*

A boolean to enable (**yes**) or disable (**no**) the local authorization for local users. For example:

```
USELOCAUTHORIZE=yes
```

USECRACKLIB=*boolean*

A boolean to enable (**yes**) or disable (**no**) using the CrackLib. For example:

```
USECRACKLIB=yes
```

USEWINBINDAUTH=*boolean*
A boolean to enable (**yes**) or disable (**no**) the Winbind authentication. For example:

```
USEWINBINDAUTH=no
```

USESMARTCARD=*boolean*
A boolean to enable (**yes**) or disable (**no**) the smart card authentication. For example:

```
USESMARTCARD=no
```

USELDAP=*boolean*
A boolean to enable (**yes**) or disable (**no**) using LDAP for user account configuration. For example:

```
USELDAP=no
```

USENIS=*boolean*
A boolean to enable (**yes**) or disable (**no**) using NIS for user account configuration. For example:

```
USENIS=no
```

USEKERBEROS=*boolean*
A boolean to enable (**yes**) or disable (**no**) the Kerberos authentication. For example:

```
USEKERBEROS=no
```

USESYSNETAUTH=*boolean*
A boolean to enable (**yes**) or disable (**no**) authenticating system accounts with network services. For example:

```
USESYSNETAUTH=no
```

USESMBAUTH=*boolean*
A boolean to enable (**yes**) or disable (**no**) the SMB authentication. For example:

```
USESMBAUTH=no
```

USESSSD=*boolean*
A boolean to enable (**yes**) or disable (**no**) using SSSD for obtaining user information. For example:

```
USESSSD=no
```

USEHESIOD=*boolean*
A boolean to enable (**yes**) or disable (**no**) using the Hesoid name service. For example:

```
USEHESIOD=no
```

Refer to *Chapter 9, Configuring Authentication* for more information on this topic.

D.1.3. /etc/sysconfig/autofs

The **/etc/sysconfig/autofs** file defines custom options for the automatic mounting of devices. This file controls the operation of the automount daemons, which automatically mount file systems when you use them and unmount them after a period of inactivity. File systems can include network file systems, CD-ROM drives, diskettes, and other media.

By default, it contains the following options:

MASTER_MAP_NAME=*value*
The default name for the master map. For example:

```
MASTER_MAP_NAME="auto.master"
```

TIMEOUT=*value*
The default mount timeout. For example:

```
TIMEOUT=300
```

NEGATIVE_TIMEOUT=*value*
The default negative timeout for unsuccessful mount attempts. For example:

```
NEGATIVE_TIMEOUT=60
```

MOUNT_WAIT=*value*
The time to wait for a response from **mount**. For example:

```
MOUNT_WAIT=-1
```

UMOUNT_WAIT=*value*
The time to wait for a response from **umount**. For example:

```
UMOUNT_WAIT=12
```

BROWSE_MODE=*boolean*
A boolean to enable (**yes**) or disable (**no**) browsing the maps. For example:

```
BROWSE_MODE="no"
```

MOUNT_NFS_DEFAULT_PROTOCOL=*value*
The default protocol to be used by **mount.nfs**. For example:

```
MOUNT_NFS_DEFAULT_PROTOCOL=4
```

APPEND_OPTIONS=*boolean*
A boolean to enable (**yes**) or disable (**no**) appending the global options instead of replacing them. For example:

```
APPEND_OPTIONS="yes"
```

LOGGING=*value*
The default logging level. The *value* has to be either **none**, **verbose**, or **debug**. For example:

```
LOGGING="none"
```

LDAP_URI=*value*
A space-separated list of server URIs in the form of *protocol*`://`*server* . For example:

```
LDAP_URI="ldaps://ldap.example.com/"
```

LDAP_TIMEOUT=*value*
The synchronous API calls timeout. For example:

```
LDAP_TIMEOUT=-1
```

LDAP_NETWORK_TIMEOUT=*value*
The network response timeout. For example:

```
LDAP_NETWORK_TIMEOUT=8
```

SEARCH_BASE=*value*
The base Distinguished Name (DN) for the map search. For example:

```
SEARCH_BASE=""
```

AUTH_CONF_FILE=*value*
The default location of the SASL authentication configuration file. For example:

```
AUTH_CONF_FILE="/etc/autofs_ldap_auth.conf"
```

MAP_HASH_TABLE_SIZE=*value*
The hash table size for the map cache. For example:

```
MAP_HASH_TABLE_SIZE=1024
```

USE_MISC_DEVICE=*boolean*
A boolean to enable (**yes**) or disable (**no**) using the autofs miscellaneous device. For example:

```
USE_MISC_DEVICE="yes"
```

OPTIONS=*value*
Additional options to be passed to the LDAP daemon. For example:

```
OPTIONS=""
```

D.1.4. /etc/sysconfig/clock

The **/etc/sysconfig/clock** file controls the interpretation of values read from the system hardware clock. It is used by the **Date and Time** configuration tool, and should not be edited by hand. By default, it contains the following option:

ZONE=*value*
The time zone file under **/usr/share/zoneinfo** that **/etc/localtime** is a copy of. For example:

```
ZONE="Europe/Prague"
```

Refer to *Section 2.1, "Using the Date and Time Configuration Tool"* for more information on the **Date and Time** configuration tool and its usage.

D.1.5. /etc/sysconfig/dhcpd

The **/etc/sysconfig/dhcpd** file is used to pass arguments to the **dhcpd** daemon at boot time. By default, it contains the following options:

DHCPDARGS=*value*
Additional options to be passed to the **dhcpd** daemon. For example:

```
DHCPDARGS=
```

Refer to *Chapter 11, DHCP Servers* for more information on DHCP and its usage.

D.1.6. /etc/sysconfig/firstboot

The **/etc/sysconfig/firstboot** file defines whether to run the **firstboot** utility. By default, it contains the following option:

RUN_FIRSTBOOT=*boolean*
A boolean to enable (**YES**) or disable (**NO**) running the **firstboot** program. For example:

```
RUN_FIRSTBOOT=NO
```

The first time the system boots, the **init** program calls the **/etc/rc.d/init.d/firstboot** script, which looks for the **/etc/sysconfig/firstboot** file. If this file does not contain the **RUN_FIRSTBOOT=NO** option, the **firstboot** program is run, guiding a user through the initial configuration of the system.



You can run the firstboot program again

To start the **firstboot** program the next time the system boots, change the value of **RUN_FIRSTBOOT** option to **YES**, and type the following at a shell prompt as `root`:

```
~]# systemctl enable firstboot.service
```

D.1.7. /etc/sysconfig/i18n

The **/etc/sysconfig/i18n** configuration file defines the default language, any supported languages, and the default system font. By default, it contains the following options:

LANG=*value*

The default language. For example:

```
LANG="en_US.UTF-8"
```

SUPPORTED=*value*

A colon-separated list of supported languages. For example:

```
SUPPORTED="en_US.UTF-8:en_US:en"
```

SYSFONT=*value*

The default system font. For example:

```
SYSFONT="latarcyrheb-sun16"
```

D.1.8. /etc/sysconfig/init

The **/etc/sysconfig/init** file controls how the system appears and functions during the boot process. By default, it contains the following options:

BOOTUP=*value*

The bootup style. The value has to be either **color** (the standard color boot display), **verbose** (an old style display which provides more information), or anything else for the new style display, but without ANSI formatting. For example:

```
BOOTUP=color
```

RES_COL=*value*

The number of the column in which the status labels start. For example:

```
RES_COL=60
```

MOVE_TO_COL=*value*

The terminal sequence to move the cursor to the column specified in **RES_COL** (see above). For example:

```
MOVE_TO_COL="echo -en \\033[${RES_COL}G"
```

SETCOLOR_SUCCESS=*value*
The terminal sequence to set the success color. For example:

```
SETCOLOR_SUCCESS="echo -en \\033[0;32m"
```

SETCOLOR_FAILURE=*value*
The terminal sequence to set the failure color. For example:

```
SETCOLOR_FAILURE="echo -en \\033[0;31m"
```

SETCOLOR_WARNING=*value*
The terminal sequence to set the warning color. For example:

```
SETCOLOR_WARNING="echo -en \\033[0;33m"
```

SETCOLOR_NORMAL=*value*
The terminal sequence to set the default color. For example:

```
SETCOLOR_NORMAL="echo -en \\033[0;39m"
```

LOGLEVEL=*value*
The initial console logging level. The *value* has to be in the range from **1** (kernel panics only) to **8** (everything, including the debugging information). For example:

```
LOGLEVEL=3
```

PROMPT=*boolean*
A boolean to enable (**yes**) or disable (**no**) the hotkey interactive startup. For example:

```
PROMPT=yes
```

AUTOSWAP=*boolean*
A boolean to enable (**yes**) or disable (**no**) probing for devices with swap signatures. For example:

```
AUTOSWAP=no
```

ACTIVE_CONSOLES=*value*
The list of active consoles. For example:

```
ACTIVE_CONSOLES=/dev/tty[1-6]
```

SINGLE=*value*
The single-user mode type. The *value* has to be either **/sbin/sulogin** (a user will be prompted for a password to log in), or **/sbin/sushell** (the user will be logged in directly). For example:

```
SINGLE=/sbin/sushell
```

D.1.9. /etc/sysconfig/ip6tables-config

The **/etc/sysconfig/ip6tables-config** file stores information used by the kernel to set up IPv6 packet filtering at boot time or whenever the **ip6tables** service is started. Note that you should not modify it unless you are familiar with **ip6tables** rules. By default, it contains the following options:

IP6TABLES_MODULES=*value*
A space-separated list of helpers to be loaded after the firewall rules are applied. For example:

```
IP6TABLES_MODULES="ip_nat_ftp ip_nat_irc"
```

IP6TABLES_MODULES_UNLOAD=*boolean*
A boolean to enable (**yes**) or disable (**no**) module unloading when the firewall is stopped or restarted. For example:

```
IP6TABLES_MODULES_UNLOAD="yes"
```

IP6TABLES_SAVE_ON_STOP=*boolean*
A boolean to enable (**yes**) or disable (**no**) saving the current firewall rules when the firewall is stopped. For example:

```
IP6TABLES_SAVE_ON_STOP="no"
```

IP6TABLES_SAVE_ON_RESTART=*boolean*
A boolean to enable (**yes**) or disable (**no**) saving the current firewall rules when the firewall is restarted. For example:

```
IP6TABLES_SAVE_ON_RESTART="no"
```

IP6TABLES_SAVE_COUNTER=*boolean*
A boolean to enable (**yes**) or disable (**no**) saving the rule and chain counters. For example:

```
IP6TABLES_SAVE_COUNTER="no"
```

IP6TABLES_STATUS_NUMERIC=*boolean*
A boolean to enable (**yes**) or disable (**no**) printing IP addresses and port numbers in a numeric format in the status output. For example:

```
IP6TABLES_STATUS_NUMERIC="yes"
```

IP6TABLES_STATUS_VERBOSE=*boolean*
A boolean to enable (**yes**) or disable (**no**) printing information about the number of packets and bytes in the status output. For example:

```
IP6TABLES_STATUS_VERBOSE="no"
```

IP6TABLES_STATUS_LINENUMBERS=*boolean*
A boolean to enable (**yes**) or disable (**no**) printing line numbers in the status output. For example:

```
IP6TABLES_STATUS_LINENUMBERS="yes"
```

Use the ip6tables command to create the rules

You can create the rules manually using the **ip6tables** command. Once created, type the following at a shell prompt:

```
~]# service ip6tables save
```

This will add the rules to **/etc/sysconfig/ip6tables**. Once this file exists, any firewall rules saved in it persist through a system reboot or a service restart.

D.1.10. /etc/sysconfig/keyboard

The **/etc/sysconfig/keyboard** file controls the behavior of the keyboard. By default, it contains the following options:

KEYTABLE=*value*
The name of a keytable file. The files that can be used as keytables start in the **/lib/kbd/keymaps/i386/** directory, and branch into different keyboard layouts from there, all labeled ***value*.kmap.gz**. The first file name that matches the **KEYTABLE** setting is used. For example:

```
KEYTABLE="us"
```

MODEL=*value*
The keyboard model. For example:

```
MODEL="pc105+inet"
```

LAYOUT=*value*
The keyboard layout. For example:

```
LAYOUT="us"
```

KEYBOARDTYPE=*value*
The keyboard type. Allowed values are **pc** (a PS/2 keyboard), or **sun** (a Sun keyboard). For example:

```
KEYBOARDTYPE="pc"
```

D.1.11. /etc/sysconfig/ldap

The **/etc/sysconfig/ldap** file holds the basic configuration for the LDAP server. By default, it contains the following options:

SLAPD_OPTIONS=*value*
Additional options to be passed to the **slapd** daemon. For example:

```
SLAPD_OPTIONS="-4"
```

SLURPD_OPTIONS=*value*
Additional options to be passed to the **slurpd** daemon. For example:

```
SLURPD_OPTIONS=""
```

SLAPD_LDAP=*boolean*
A boolean to enable (**yes**) or disable (**no**) using the LDAP over TCP (that is, `ldap:///`). For example:

```
SLAPD_LDAP="yes"
```

SLAPD_LDAPI=*boolean*
A boolean to enable (**yes**) or disable (**no**) using the LDAP over IPC (that is, `ldapi:///`). For example:

```
SLAPD_LDAPI="no"
```

SLAPD_LDAPS=*boolean*
A boolean to enable (**yes**) or disable (**no**) using the LDAP over TLS (that is, `ldaps:///`). For example:

```
SLAPD_LDAPS="no"
```

SLAPD_URLS=*value*
A space-separated list of URLs. For example:

```
SLAPD_URLS="ldapi:///var/lib/ldap_root/ldapi ldapi:/// ldaps:///"
```

SLAPD_SHUTDOWN_TIMEOUT=*value*
The time to wait for **slapd** to shut down. For example:

```
SLAPD_SHUTDOWN_TIMEOUT=3
```

SLAPD_ULIMIT_SETTINGS=*value*
The parameters to be passed to **ulimit** before the **slapd** daemon is started. For example:

```
SLAPD_ULIMIT_SETTINGS=""
```

Refer to *Section 15.1, “OpenLDAP”* for more information on LDAP and its configuration.

D.1.12. /etc/sysconfig/named

The **/etc/sysconfig/named** file is used to pass arguments to the **named** daemon at boot time. By default, it contains the following options:

ROOTDIR=*value*
The chroot environment under which the **named** daemon runs. The *value* has to be a full directory path. For example:

```
ROOTDIR="/var/named/chroot"
```

Note that the chroot environment has to be configured first (type **info chroot** at a shell prompt for more information).

OPTIONS=*value*
Additional options to be passed to **named**. For example:

```
OPTIONS="-6"
```

Note that you should not use the **-t** option. Instead, use **ROOTDIR** as described above.

KEYTAB_FILE=*value*
The keytab file name. For example:

```
KEYTAB_FILE="/etc/named.keytab"
```

Refer to *Section 12.2, "BIND"* for more information on the BIND DNS server and its configuration.

D.1.13. /etc/sysconfig/network

The **/etc/sysconfig/network** file is used to specify information about the desired network configuration. By default, it contains the following options:

NETWORKING=*boolean*
A boolean to enable (**yes**) or disable (**no**) the networking. For example:

```
NETWORKING=yes
```

HOSTNAME=*value*
The hostname of the machine. For example:

```
HOSTNAME=penguin.example.com
```

GATEWAY=*value*
The IP address of the network's gateway. For example:

```
GATEWAY=192.168.1.0
```



Avoid using custom init scripts

Do not use custom init scripts to configure network settings. When performing a post-boot network service restart, custom init scripts configuring network settings that are run outside of the network init script lead to unpredictable results.

D.1.14. /etc/sysconfig/ntpd

The **/etc/sysconfig/ntpd** file is used to pass arguments to the **ntpd** daemon at boot time. By default, it contains the following option:

OPTIONS=*value*
Additional options to be passed to **ntpd**. For example:

```
OPTIONS="-u ntp:ntp -p /var/run/ntpd.pid -g"
```

Refer to *Section 2.2.3, "Configuring the Network Time Protocol"* for more information on how to configure the **ntpd** daemon.

D.1.15. /etc/sysconfig/quagga

The **/etc/sysconfig/quagga** file holds the basic configuration for Quagga daemons. By default, it contains the following options:

QCONFDIR=*value*
The directory with the configuration files for Quagga daemons. For example:

```
QCONFDIR="/etc/quagga"
```

BGPD_OPTS=*value*
Additional options to be passed to the **bgpd** daemon. For example:

```
BGPD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/bgpd.conf"
```

OSPF6D_OPTS=*value*
Additional options to be passed to the **ospf6d** daemon. For example:

```
OSPF6D_OPTS="-A ::1 -f ${QCONFDIR}/ospf6d.conf"
```

OSPFD_OPTS=*value*
Additional options to be passed to the **ospfd** daemon. For example:

```
OSPFD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/ospfd.conf"
```

RIPD_OPTS=*value*
Additional options to be passed to the **ripd** daemon. For example:

```
RIPD_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/ripd.conf"
```

RIPNGD_OPTS=*value*
Additional options to be passed to the **ripngd** daemon. For example:

```
RIPNGD_OPTS="-A ::1 -f ${QCONFDIR}/ripngd.conf"
```

ZEBRA_OPTS=*value*
Additional options to be passed to the **zebra** daemon. For example:

```
ZEBRA_OPTS="-A 127.0.0.1 -f ${QCONFDIR}/zebra.conf"
```

ISISD_OPTS=*value*
Additional options to be passed to the **isisd** daemon. For example:

```
ISISD_OPTS="-A ::1 -f ${QCONFDIR}/isisd.conf"
```

WATCH_OPTS=*value*
Additional options to be passed to the **watchquagga** daemon. For example:

```
WATCH_OPTS="-Az -b_ -r/sbin/service_%s_restart -s/sbin/service_%s_start -k/sbin/service_
%s_stop"
```

WATCH_DAEMONS=*value*
A space separated list of monitored daemons. For example:

```
WATCH_DAEMONS="zebra bgpd ospfd ospf6d ripd ripngd"
```

D.1.16. /etc/sysconfig/radvd

The **/etc/sysconfig/radvd** file is used to pass arguments to the **radvd** daemon at boot time. By default, it contains the following option:

OPTIONS=*value*
Additional options to be passed to the **radvd** daemon. For example:

```
OPTIONS="-u radvd"
```

D.1.17. /etc/sysconfig/samba

The **/etc/sysconfig/samba** file is used to pass arguments to the Samba daemons at boot time. By default, it contains the following options:

SMBDOPTIONS=*value*
Additional options to be passed to **smbd**. For example:

```
SMBDOPTIONS="-D"
```

NMBDOPTIONS=*value*
Additional options to be passed to **nmbd**. For example:

```
NMBDOPTIONS="-D"
```

WINBINDOPTIONS=*value*
Additional options to be passed to **winbindd**. For example:

```
WINBINDOPTIONS=""
```

Refer to *Section 16.1, "Samba"* for more information on Samba and its configuration.

D.1.18. /etc/sysconfig/selinux

The **/etc/sysconfig/selinux** file contains the basic configuration options for SELinux. It is a symbolic link to **/etc/selinux/config**, and by default, it contains the following options:

SELINUX=*value*
The security policy. The *value* can be either **enforcing** (the security policy is always enforced), **permissive** (instead of enforcing the policy, appropriate warnings are displayed), or **disabled** (no policy is used). For example:

```
SELINUX=enforcing
```

SELINUXTYPE=*value*
The protection type. The *value* can be either **targeted** (the targeted processes are protected), or **mls** (the Multi Level Security protection). For example:

```
SELINUXTYPE=targeted
```

D.1.19. /etc/sysconfig/sendmail

The **/etc/sysconfig/sendmail** is used to set the default values for the **Sendmail** application. By default, it contains the following values:

DAEMON=*boolean*
A boolean to enable (**yes**) or disable (**no**) running **sendmail** as a daemon. For example:

```
DAEMON=yes
```

QUEUE=*value*
The interval at which the messages are to be processed. For example:

```
QUEUE=1h
```

Refer to *Section 14.3.2, "Sendmail"* for more information on Sendmail and its configuration.

D.1.20. /etc/sysconfig/spamassassin

The **/etc/sysconfig/spamassassin** file is used to pass arguments to the **spamd** daemon (a daemonized version of **Spamassassin**) at boot time. By default, it contains the following option:

SPAMDOPTIONS=*value*
Additional options to be passed to the **spamd** daemon. For example:

```
SPAMDOPTIONS="-d -c -m5 -H"
```

Refer to *Section 14.4.2.6, "Spam Filters"* for more information on Spamassassin and its configuration.

D.1.21. /etc/sysconfig/squid

The **/etc/sysconfig/squid** file is used to pass arguments to the **squid** daemon at boot time. By default, it contains the following options:

SQUID_OPTS=*value*
Additional options to be passed to the **squid** daemon. For example:

```
SQUID_OPTS=""
```

SQUID_SHUTDOWN_TIMEOUT=*value*
The time to wait for **squid** daemon to shut down. For example:

```
SQUID_SHUTDOWN_TIMEOUT=100
```

SQUID_CONF=*value*
The default configuration file. For example:

```
SQUID_CONF="/etc/squid/squid.conf"
```

D.1.22. /etc/sysconfig/system-config-users

The **/etc/sysconfig/system-config-users** file is the configuration file for the **User Manager** utility, and should not be edited by hand. By default, it contains the following options:

FILTER=*boolean*
A boolean to enable (**true**) or disable (**false**) filtering of system users. For example:

```
FILTER=true
```

ASSIGN_HIGHEST_UID=*boolean*
A boolean to enable (**true**) or disable (**false**) assigning the highest available UID to newly added users. For example:

```
ASSIGN_HIGHEST_UID=true
```

ASSIGN_HIGHEST_GID=*boolean*
A boolean to enable (**true**) or disable (**false**) assigning the highest available GID to newly added groups. For example:

```
ASSIGN_HIGHEST_GID=true
```

PREFER_SAME_UID_GID=*boolean*
A boolean to enable (**true**) or disable (**false**) using the same UID and GID for newly added users when possible. For example:

```
PREFER_SAME_UID_GID=true
```

Refer to *Section 3.3, "Using the User Manager Tool"* for more information on **User Manager** and its usage.

D.1.23. /etc/sysconfig/vncservers

The **/etc/sysconfig/vncservers** file configures the way the *Virtual Network Computing* (*VNC*) server starts up. By default, it contains the following options:

VNCSERVERS=*value*
A list of space separated ***display*:*username*** pairs. For example:

```
VNCSERVERS="2:myusername"
```

VNCSERVERARGS[*display*]=*value*
Additional arguments to be passed to the VNC server running on the specified *display*. For example:

```
VNCSERVERARGS[2]="-geometry 800x600 -nolisten tcp -localhost"
```

D.1.24. /etc/sysconfig/xinetd

The **/etc/sysconfig/xinetd** file is used to pass arguments to the **xinetd** daemon at boot time. By default, it contains the following options:

EXTRAOPTIONS=*value*
Additional options to be passed to **xinetd**. For example:

```
EXTRAOPTIONS=""
```

XINETD_LANG=*value*
The locale information to be passed to every service started by **xinetd**. Note that to remove locale information from the **xinetd** environment, you can use an empty string (**""**) or **none**. For example:

```
XINETD_LANG="en_US"
```

Refer to *Chapter 8, Services and Daemons* for more information on how to configure the **xinetd** services.

D.2. Directories in the /etc/sysconfig/ Directory

The following directories are normally found in **/etc/sysconfig/**.

/etc/sysconfig/cbq/
This directory contains the configuration files needed to do *Class Based Queuing* for bandwidth management on network interfaces. CBQ divides user traffic into a hierarchy of classes based on any combination of IP addresses, protocols, and application types.

/etc/sysconfig/networking/
This directory is used by the **Network Administration Tool** (**system-config-network**), and its contents should not be edited manually.

/etc/sysconfig/network-scripts/
This directory contains the following network-related configuration files:

- Network configuration files for each configured network interface, such as **ifcfg-eth0** for the `eth0` Ethernet interface.
- Scripts used to bring network interfaces up and down, such as **ifup** and **ifdown**.
- Scripts used to bring ISDN interfaces up and down, such as **ifup-isdn** and **ifdown-isdn**.
- Various shared network function scripts which should not be edited directly.

For more information on the **/etc/sysconfig/network-scripts/** directory, refer to *Chapter 7, Network Interfaces*.

D.3. Additional Resources

This chapter is only intended as an introduction to the files in the **/etc/sysconfig/** directory. The following source contains more comprehensive information.

D.3.1. Installed Documentation

/usr/share/doc/initscripts-*version*/sysconfig.txt
A more authoritative listing of the files found in the **/etc/sysconfig/** directory and the configuration options available for them.

Appendix E. The proc File System

The Linux kernel has two primary functions: to control access to physical devices on the computer and to schedule when and how processes interact with these devices. The **/proc/** directory (also called the **proc** file system) contains a hierarchy of special files which represent the current state of the kernel, allowing applications and users to peer into the kernel's view of the system.

The **/proc/** directory contains a wealth of information detailing system hardware and any running processes. In addition, some of the files within **/proc/** can be manipulated by users and applications to communicate configuration changes to the kernel.



The /proc/ide/ and /proc/pci/ directories

Later versions of the 2.6 kernel have made the **/proc/ide/** and **/proc/pci/** directories obsolete. The **/proc/ide/** file system is now superseded by files in **sysfs**; to retrieve information on PCI devices, use **lspci** instead. For more information on **sysfs** or **lspci**, refer to their respective **man** pages.

E.1. A Virtual File System

Linux systems store all data as *files*. Most users are familiar with the two primary types of files: text and binary. But the **/proc/** directory contains another type of file called a *virtual file*. As such, **/proc/** is often referred to as a *virtual file system*.

Virtual files have unique qualities. Most of them are listed as zero bytes in size, but can still contain a large amount of information when viewed. In addition, most of the time and date stamps on virtual files reflect the current time and date, indicative of the fact they are constantly updated.

Virtual files such as **/proc/interrupts**, **/proc/meminfo**, **/proc/mounts**, and **/proc/partitions** provide an up-to-the-moment glimpse of the system's hardware. Others, like the **/proc/filesystems** file and the **/proc/sys/** directory provide system configuration information and interfaces.

For organizational purposes, files containing information on a similar topic are grouped into virtual directories and sub-directories. Process directories contain information about each running process on the system.

E.1.1. Viewing Virtual Files

Most files within **/proc/** files operate similarly to text files, storing useful system and hardware data in human-readable text format. As such, you can use **cat**, **more**, or **less** to view them. For example, to display information about the system's CPU, run **cat /proc/cpuinfo**. This will return output similar to the following:

```
processor : 0
vendor_id : AuthenticAMD
cpu family : 5
model  : 9
model name : AMD-K6(tm) 3D+
```

```
Processor stepping : 1 cpu
MHz  : 400.919
cache size : 256 KB
fdiv_bug : no
hlt_bug  : no
f00f_bug : no
coma_bug : no
fpu  : yes
fpu_exception : yes
cpuid level : 1
wp  : yes
flags  : fpu vme de pse tsc msr mce cx8 pge mmx syscall 3dnow k6_mtrr
bogomips : 799.53
```

Some files in **/proc/** contain information that is not human-readable. To retrieve information from such files, use tools such as **lspci**, **apm**, **free**, and **top**.

Certain files can only be accessed with root privileges

Some of the virtual files in the **/proc/** directory are readable only by the root user.

E.1.2. Changing Virtual Files

As a general rule, most virtual files within the **/proc/** directory are read-only. However, some can be used to adjust settings in the kernel. This is especially true for files in the **/proc/sys/** subdirectory.

To change the value of a virtual file, use the following command:

echo *value* > /proc/*file*

For example, to change the hostname on the fly, run:

echo *www.example.com* > /proc/sys/kernel/hostname

Other files act as binary or Boolean switches. Typing **cat /proc/sys/net/ipv4/ip_forward** returns either a **0** (off or false) or a **1** (on or true). A **0** indicates that the kernel is not forwarding network packets. To turn packet forwarding on, run **echo 1 > /proc/sys/net/ipv4/ip_forward**.

The sysctl command

Another command used to alter settings in the **/proc/sys/** subdirectory is **/sbin/sysctl**. For more information on this command, refer to *Section E.4, "Using the sysctl Command"*

For a listing of some of the kernel configuration files available in the **/proc/sys/** subdirectory, refer to *Section E.3.9, " /proc/sys/ "*.

E.2. Top-level Files within the proc File System

Below is a list of some of the more useful virtual files in the top-level of the **/proc/** directory.

The content of your files may differ

In most cases, the content of the files listed in this section are not the same as those installed on your machine. This is because much of the information is specific to the hardware on which Fedora is running for this documentation effort.

E.2.1. /proc/buddyinfo

This file is used primarily for diagnosing memory fragmentation issues. Using the buddy algorithm, each column represents the number of pages of a certain order (a certain size) that are available at any given time. For example, for zone *direct memory access* (DMA), there are 90 of $2^{(0*PAGE\_SIZE)}$ chunks of memory. Similarly, there are 6 of $2^{(1*PAGE\_SIZE)}$ chunks, and 2 of $2^{(2*PAGE\_SIZE)}$ chunks of memory available.

The **DMA** row references the first 16 MB on a system, the **HighMem** row references all memory greater than 4 GB on a system, and the **Normal** row references all memory in between.

The following is an example of the output typical of **/proc/buddyinfo**:

```
Node 0, zone      DMA     90      6      2      1      1      ...
Node 0, zone   Normal   1650    310      5      0      0      ...
Node 0, zone  HighMem      2      0      0      1      1      ...
```

E.2.2. /proc/cmdline

This file shows the parameters passed to the kernel at the time it is started. A sample **/proc/cmdline** file looks like the following:

```
ro root=/dev/VolGroup00/LogVol00 rhgb quiet 3
```

This tells us that the kernel is mounted read-only (signified by **(ro)**), located on the first logical volume (**LogVol00**) of the first volume group (**/dev/VolGroup00**). **LogVol00** is the equivalent of a disk partition in a non-LVM system (Logical Volume Management), just as **/dev/VolGroup00** is similar in concept to **/dev/hda1**, but much more extensible.

For more information on LVM used in Fedora, refer to *http://www.tldp.org/HOWTO/LVM-HOWTO/index.html*.

Next, **rhgb** signals that the **rhgb** package has been installed, and graphical booting is supported, assuming **/etc/inittab** shows a default runlevel set to **id:5:initdefault:**.

Finally, **quiet** indicates all verbose kernel messages are suppressed at boot time.

E.2.3. /proc/cpuinfo

This virtual file identifies the type of processor used by your system. The following is an example of the output typical of **/proc/cpuinfo**:

```
processor : 0
vendor_id : GenuineIntel
cpu family : 15
model  : 2
model name : Intel(R) Xeon(TM) CPU 2.40GHz
stepping : 7 cpu
MHz  : 2392.371
cache size : 512 KB
physical id : 0
siblings : 2
runqueue : 0
fdiv_bug : no
hlt_bug  : no
f00f_bug : no
coma_bug : no
fpu  : yes
fpu_exception : yes
cpuid level : 2
wp  : yes
flags  : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca  cmov pat pse36 clflush dts
 acpi mmx fxsr sse sse2 ss ht tm
bogomips : 4771.02
```

- **processor** — Provides each processor with an identifying number. On systems that have one processor, only a **0** is present.
- **cpu family** — Authoritatively identifies the type of processor in the system. For an Intel-based system, place the number in front of "86" to determine the value. This is particularly helpful for those attempting to identify the architecture of an older system such as a 586, 486, or 386. Because some RPM packages are compiled for each of these particular architectures, this value also helps users determine which packages to install.
- **model name** — Displays the common name of the processor, including its project name.
- **cpu MHz** — Shows the precise speed in megahertz for the processor to the thousandths decimal place.
- **cache size** — Displays the amount of level 2 memory cache available to the processor.
- **siblings** — Displays the number of sibling CPUs on the same physical CPU for architectures which use hyper-threading.
- **flags** — Defines a number of different qualities about the processor, such as the presence of a floating point unit (FPU) and the ability to process MMX instructions.

E.2.4. /proc/crypto

This file lists all installed cryptographic ciphers used by the Linux kernel, including additional details for each. A sample **/proc/crypto** file looks like the following:

```
name         : sha1
module       : kernel
type         : digest
blocksize    : 64
```

```
digestsize   : 20
name         : md5
module       : md5
type         : digest
blocksize    : 64
digestsize   : 16
```

E.2.5. /proc/devices

This file displays the various character and block devices currently configured (not including devices whose modules are not loaded). Below is a sample output from this file:

```
Character devices:
  1 mem
  4 /dev/vc/0
  4 tty
  4 ttyS
  5 /dev/tty
  5 /dev/console
  5 /dev/ptmx
  7 vcs
  10 misc
  13 input
  29 fb
  36 netlink
  128 ptm
  136 pts
  180 usb

Block devices:
  1 ramdisk
  3 ide0
  9 md
  22 ide1
  253 device-mapper
  254 mdp
```

The output from **/proc/devices** includes the major number and name of the device, and is broken into two major sections: **Character devices** and **Block devices**.

Character devices are similar to *block devices*, except for two basic differences:

1. Character devices do not require buffering. Block devices have a buffer available, allowing them to order requests before addressing them. This is important for devices designed to store information — such as hard drives — because the ability to order the information before writing it to the device allows it to be placed in a more efficient order.

2. Character devices send data with no preconfigured size. Block devices can send and receive information in blocks of a size configured per device.

For more information about devices refer to the following installed documentation:

```
/usr/share/doc/kernel-doc-<kernel_version>/Documentation/devices.txt
```

E.2.6. /proc/dma

This file contains a list of the registered ISA DMA channels in use. A sample **/proc/dma** files looks like the following:

```
4: cascade
```

E.2.7. /proc/execdomains

This file lists the *execution domains* currently supported by the Linux kernel, along with the range of personalities they support.

```
0-0   Linux           [kernel]
```

Think of execution domains as the "personality" for an operating system. Because other binary formats, such as Solaris, UnixWare, and FreeBSD, can be used with Linux, programmers can change the way the operating system treats system calls from these binaries by changing the personality of the task. Except for the **PER_LINUX** execution domain, different personalities can be implemented as dynamically loadable modules.

E.2.8. /proc/fb

This file contains a list of frame buffer devices, with the frame buffer device number and the driver that controls it. Typical output of **/proc/fb** for systems which contain frame buffer devices looks similar to the following:

```
0 VESA VGA
```

E.2.9. /proc/filesystems

This file displays a list of the file system types currently supported by the kernel. Sample output from a generic **/proc/filesystems** file looks similar to the following:

```
nodev   sysfs
nodev   rootfs
nodev   bdev
nodev   proc
nodev   sockfs
nodev   binfmt_misc
nodev   usbfs
nodev   usbdevfs
nodev   futexfs
nodev   tmpfs
nodev   pipefs
nodev   eventpollfs
nodev   devpts
 ext2
nodev   ramfs
nodev   hugetlbfs
 iso9660
nodev   mqueue
```

```
 ext3
nodev   rpc_pipefs
nodev   autofs
```

The first column signifies whether the file system is mounted on a block device. Those beginning with **nodev** are not mounted on a device. The second column lists the names of the file systems supported.

The **mount** command cycles through the file systems listed here when one is not specified as an argument.

E.2.10. /proc/interrupts

This file records the number of interrupts per IRQ on the x86 architecture. A standard **/proc/interrupts** looks similar to the following:

```
  CPU0
  0:   80448940          XT-PIC  timer
  1:     174412          XT-PIC  keyboard
  2:          0          XT-PIC  cascade
  8:          1          XT-PIC  rtc
 10:     410964          XT-PIC  eth0
 12:      60330          XT-PIC  PS/2 Mouse
 14:    1314121          XT-PIC  ide0
 15:    5195422          XT-PIC  ide1
NMI:          0
ERR:          0
```

For a multi-processor machine, this file may look slightly different:

```
    CPU0       CPU1
  0: 1366814704          0          XT-PIC  timer
  1:        128        340    IO-APIC-edge  keyboard
  2:          0          0          XT-PIC  cascade
  8:          0          1    IO-APIC-edge  rtc
 12:       5323       5793    IO-APIC-edge  PS/2 Mouse
 13:          1          0          XT-PIC  fpu
 16:   11184294   15940594   IO-APIC-level  Intel EtherExpress Pro 10/100 Ethernet
 20:    8450043   11120093   IO-APIC-level  megaraid
 30:      10432      10722   IO-APIC-level  aic7xxx
 31:         23         22   IO-APIC-level  aic7xxx
NMI:          0
ERR:          0
```

The first column refers to the IRQ number. Each CPU in the system has its own column and its own number of interrupts per IRQ. The next column reports the type of interrupt, and the last column contains the name of the device that is located at that IRQ.

Each of the types of interrupts seen in this file, which are architecture-specific, mean something different. For x86 machines, the following values are common:

- **XT-PIC** — This is the old AT computer interrupts.
- **IO-APIC-edge** — The voltage signal on this interrupt transitions from low to high, creating an *edge*, where the interrupt occurs and is only signaled once. This kind of interrupt, as well as the **IO-APIC-level** interrupt, are only seen on systems with processors from the 586 family and higher.

- **IO-APIC-level** — Generates interrupts when its voltage signal is high until the signal is low again.

E.2.11. /proc/iomem

This file shows you the current map of the system's memory for each physical device:

```
00000000-0009fbff : System RAM
0009fc00-0009ffff : reserved
000a0000-000bffff : Video RAM area
000c0000-000c7fff : Video ROM
000f0000-000fffff : System ROM
00100000-07ffffff : System RAM
00100000-00291ba8 : Kernel code
00291ba9-002e09cb : Kernel data
e0000000-e3ffffff : VIA Technologies, Inc. VT82C597 [Apollo VP3] e4000000-e7ffffff : PCI Bus
 #01
e4000000-e4003fff : Matrox Graphics, Inc. MGA G200 AGP
e5000000-e57fffff : Matrox Graphics, Inc. MGA G200 AGP
e8000000-e8ffffff : PCI Bus #01
e8000000-e8ffffff : Matrox Graphics, Inc. MGA G200 AGP
ea000000-ea00007f : Digital Equipment Corporation DECchip 21140 [FasterNet]
ea000000-ea00007f : tulip ffff0000-ffffffff : reserved
```

The first column displays the memory registers used by each of the different types of memory. The second column lists the kind of memory located within those registers and displays which memory registers are used by the kernel within the system RAM or, if the network interface card has multiple Ethernet ports, the memory registers assigned for each port.

E.2.12. /proc/ioports

The output of **/proc/ioports** provides a list of currently registered port regions used for input or output communication with a device. This file can be quite long. The following is a partial listing:

```
0000-001f : dma1
0020-003f : pic1
0040-005f : timer
0060-006f : keyboard
0070-007f : rtc
0080-008f : dma page reg
00a0-00bf : pic2
00c0-00df : dma2
00f0-00ff : fpu
0170-0177 : ide1
01f0-01f7 : ide0
02f8-02ff : serial(auto)
0376-0376 : ide1
03c0-03df : vga+
03f6-03f6 : ide0
03f8-03ff : serial(auto)
0cf8-0cff : PCI conf1
d000-dfff : PCI Bus #01
e000-e00f : VIA Technologies, Inc. Bus Master IDE
e000-e007 : ide0
e008-e00f : ide1
e800-e87f : Digital Equipment Corporation DECchip 21140 [FasterNet]
e800-e87f : tulip
```

The first column gives the I/O port address range reserved for the device listed in the second column.

E.2.13. /proc/kcore

This file represents the physical memory of the system and is stored in the core file format. Unlike most **/proc/** files, **kcore** displays a size. This value is given in bytes and is equal to the size of the physical memory (RAM) used plus 4 KB.

The contents of this file are designed to be examined by a debugger, such as **gdb**, and is not human readable.



Do not attempt to view the content of /proc/kcore

Do not view the **/proc/kcore** virtual file. The contents of the file scramble text output on the terminal. If this file is accidentally viewed, press **Ctrl**+**C** to stop the process and then type **reset** to bring back the command line prompt.

E.2.14. /proc/kmsg

This file is used to hold messages generated by the kernel. These messages are then picked up by other programs, such as **/sbin/klogd** or **/bin/dmesg**.

E.2.15. /proc/loadavg

This file provides a look at the load average in regard to both the CPU and IO over time, as well as additional data used by **uptime** and other commands. A sample **/proc/loadavg** file looks similar to the following:

```
0.20 0.18 0.12 1/80 11206
```

The first three columns measure CPU and IO utilization of the last one, five, and 15 minute periods. The fourth column shows the number of currently running processes and the total number of processes. The last column displays the last process ID used.

In addition, load average also refers to the number of processes ready to run (i.e. in the run queue, waiting for a CPU share.

E.2.16. /proc/locks

This file displays the files currently locked by the kernel. The contents of this file contain internal kernel debugging data and can vary tremendously, depending on the use of the system. A sample **/proc/locks** file for a lightly loaded system looks similar to the following:

```
1: POSIX  ADVISORY  WRITE 3568 fd:00:2531452 0 EOF
2: FLOCK  ADVISORY  WRITE 3517 fd:00:2531448 0 EOF
3: POSIX  ADVISORY  WRITE 3452 fd:00:2531442 0 EOF
```

```
4: POSIX  ADVISORY  WRITE 3443 fd:00:2531440 0 EOF
5: POSIX  ADVISORY  WRITE 3326 fd:00:2531430 0 EOF
6: POSIX  ADVISORY  WRITE 3175 fd:00:2531425 0 EOF
7: POSIX  ADVISORY  WRITE 3056 fd:00:2548663 0 EOF
```

Each lock has its own line which starts with a unique number. The second column refers to the class of lock used, with **FLOCK** signifying the older-style UNIX file locks from a **flock** system call and **POSIX** representing the newer POSIX locks from the **lockf** system call.

The third column can have two values: **ADVISORY** or **MANDATORY**. **ADVISORY** means that the lock does not prevent other people from accessing the data; it only prevents other attempts to lock it. **MANDATORY** means that no other access to the data is permitted while the lock is held. The fourth column reveals whether the lock is allowing the holder **READ** or **WRITE** access to the file. The fifth column shows the ID of the process holding the lock. The sixth column shows the ID of the file being locked, in the format of ***MAJOR-DEVICE*:*MINOR-DEVICE*:*INODE-NUMBER*** . The seventh and eighth column shows the start and end of the file's locked region.

E.2.17. /proc/mdstat

This file contains the current information for multiple-disk, RAID configurations. If the system does not contain such a configuration, then **/proc/mdstat** looks similar to the following:

```
Personalities :  read_ahead not set unused devices: <none>
```

This file remains in the same state as seen above unless a software RAID or **md** device is present. In that case, view **/proc/mdstat** to find the current status of **md*X*** RAID devices.

The **/proc/mdstat** file below shows a system with its **md0** configured as a RAID 1 device, while it is currently re-syncing the disks:

```
Personalities : [linear] [raid1] read_ahead 1024 sectors
md0: active raid1 sda2[1] sdb2[0] 9940 blocks [2/2] [UU] resync=1% finish=12.3min algorithm 2
 [3/3] [UUU]
unused devices: <none>
```

E.2.18. /proc/meminfo

This is one of the more commonly used files in the **/proc/** directory, as it reports a large amount of valuable information about the systems RAM usage.

The following sample **/proc/meminfo** virtual file is from a system with 256 MB of RAM and 512 MB of swap space:

```
MemTotal:       255908 kB
MemFree:         69936 kB
Buffers:         15812 kB
Cached:         115124 kB
SwapCached:          0 kB
Active:          92700 kB
Inactive:        63792 kB
HighTotal:           0 kB
HighFree:            0 kB
```

```
LowTotal:       255908 kB
LowFree:         69936 kB
SwapTotal:      524280 kB
SwapFree:       524280 kB
Dirty:               4 kB
Writeback:           0 kB
Mapped:          42236 kB
Slab:            25912 kB
Committed_AS:   118680 kB
PageTables:       1236 kB
VmallocTotal:  3874808 kB
VmallocUsed:      1416 kB
VmallocChunk:  3872908 kB
HugePages_Total:     0
HugePages_Free:      0
Hugepagesize:     4096 kB
```

Much of the information here is used by the **free**, **top**, and **ps** commands. In fact, the output of the **free** command is similar in appearance to the contents and structure of **/proc/meminfo**. But by looking directly at **/proc/meminfo**, more details are revealed:

- **MemTotal** — Total amount of physical RAM, in kilobytes.
- **MemFree** — The amount of physical RAM, in kilobytes, left unused by the system.
- **Buffers** — The amount of physical RAM, in kilobytes, used for file buffers.
- **Cached** — The amount of physical RAM, in kilobytes, used as cache memory.
- **SwapCached** — The amount of swap, in kilobytes, used as cache memory.
- **Active** — The total amount of buffer or page cache memory, in kilobytes, that is in active use. This is memory that has been recently used and is usually not reclaimed for other purposes.
- **Inactive** — The total amount of buffer or page cache memory, in kilobytes, that are free and available. This is memory that has not been recently used and can be reclaimed for other purposes.
- **HighTotal** and **HighFree** — The total and free amount of memory, in kilobytes, that is not directly mapped into kernel space. The **HighTotal** value can vary based on the type of kernel used.
- **LowTotal** and **LowFree** — The total and free amount of memory, in kilobytes, that is directly mapped into kernel space. The **LowTotal** value can vary based on the type of kernel used.
- **SwapTotal** — The total amount of swap available, in kilobytes.
- **SwapFree** — The total amount of swap free, in kilobytes.
- **Dirty** — The total amount of memory, in kilobytes, waiting to be written back to the disk.
- **Writeback** — The total amount of memory, in kilobytes, actively being written back to the disk.
- **Mapped** — The total amount of memory, in kilobytes, which have been used to map devices, files, or libraries using the **mmap** command.
- **Slab** — The total amount of memory, in kilobytes, used by the kernel to cache data structures for its own use.
- **Committed_AS** — The total amount of memory, in kilobytes, estimated to complete the workload. This value represents the worst case scenario value, and also includes swap memory.
- **PageTables** — The total amount of memory, in kilobytes, dedicated to the lowest page table level.

- **VMallocTotal** — The total amount of memory, in kilobytes, of total allocated virtual address space.
- **VMallocUsed** — The total amount of memory, in kilobytes, of used virtual address space.
- **VMallocChunk** — The largest contiguous block of memory, in kilobytes, of available virtual address space.
- **HugePages_Total** — The total number of hugepages for the system. The number is derived by dividing **Hugepagesize** by the megabytes set aside for hugepages specified in **/proc/sys/vm/hugetlb_pool**. *This statistic only appears on the x86, Itanium, and AMD64 architectures.*
- **HugePages_Free** — The total number of hugepages available for the system. *This statistic only appears on the x86, Itanium, and AMD64 architectures.*
- **Hugepagesize** — The size for each hugepages unit in kilobytes. By default, the value is 4096 KB on uniprocessor kernels for 32 bit architectures. For SMP, hugemem kernels, and AMD64, the default is 2048 KB. For Itanium architectures, the default is 262144 KB. *This statistic only appears on the x86, Itanium, and AMD64 architectures.*

E.2.19. /proc/misc

This file lists miscellaneous drivers registered on the miscellaneous major device, which is device number 10:

```
63 device-mapper 175 agpgart 135 rtc 134 apm_bios
```

The first column is the minor number of each device, while the second column shows the driver in use.

E.2.20. /proc/modules

This file displays a list of all modules loaded into the kernel. Its contents vary based on the configuration and use of your system, but it should be organized in a similar manner to this sample **/proc/modules** file output:



The content of /proc/modules

This example has been reformatted into a readable format. Most of this information can also be viewed via the **/sbin/lsmod** command.

```
nfs      170109  0 -          Live 0x129b0000
lockd    51593   1 nfs,       Live 0x128b0000
nls_utf8 1729    0 -          Live 0x12830000
vfat     12097   0 -          Live 0x12823000
fat      38881   1 vfat,      Live 0x1287b000
autofs4  20293   2 -          Live 0x1284f000
sunrpc   140453  3 nfs,lockd, Live 0x12954000
3c59x    33257   0 -          Live 0x12871000
uhci_hcd 28377   0 -          Live 0x12869000
```

```
md5      3777    1 -          Live 0x1282c000
ipv6     211845 16 -          Live 0x128de000
ext3     92585   2 -          Live 0x12886000
jbd      65625   1 ext3,      Live 0x12857000
dm_mod   46677   3 -          Live 0x12833000
```

The first column contains the name of the module.

The second column refers to the memory size of the module, in bytes.

The third column lists how many instances of the module are currently loaded. A value of zero represents an unloaded module.

The fourth column states if the module depends upon another module to be present in order to function, and lists those other modules.

The fifth column lists what load state the module is in: **`Live`**, **`Loading`**, or **`Unloading`** are the only possible values.

The sixth column lists the current kernel memory offset for the loaded module. This information can be useful for debugging purposes, or for profiling tools such as **`oprofile`**.

E.2.21. /proc/mounts

This file provides a list of all mounts in use by the system:

```
rootfs / rootfs rw 0 0
/proc /proc proc rw,nodiratime 0 0 none
/dev ramfs rw 0 0
/dev/mapper/VolGroup00-LogVol00 / ext3 rw 0 0
none /dev ramfs rw 0 0
/proc /proc proc rw,nodiratime 0 0
/sys /sys sysfs rw 0 0
none /dev/pts devpts rw 0 0
usbdevfs /proc/bus/usb usbdevfs rw 0 0
/dev/hda1 /boot ext3 rw 0 0
none /dev/shm tmpfs rw 0 0
none /proc/sys/fs/binfmt_misc binfmt_misc rw 0 0
sunrpc /var/lib/nfs/rpc_pipefs rpc_pipefs rw 0 0
```

The output found here is similar to the contents of **`/etc/mtab`**, except that **`/proc/mounts`** is more up-to-date.

The first column specifies the device that is mounted, the second column reveals the mount point, and the third column tells the file system type, and the fourth column tells you if it is mounted read-only (**`ro`**) or read-write (**`rw`**). The fifth and sixth columns are dummy values designed to match the format used in **`/etc/mtab`**.

E.2.22. /proc/mtrr

This file refers to the current Memory Type Range Registers (MTRRs) in use with the system. If the system architecture supports MTRRs, then the **`/proc/mtrr`** file may look similar to the following:

```
reg00: base=0x00000000 (   0MB), size= 256MB: write-back, count=1
reg01: base=0xe8000000 (3712MB), size=  32MB: write-combining, count=1
```

MTRRs are used with the Intel P6 family of processors (Pentium II and higher) and control processor access to memory ranges. When using a video card on a PCI or AGP bus, a properly configured **/proc/mtrr** file can increase performance more than 150%.

Most of the time, this value is properly configured by default. More information on manually configuring this file can be found locally at the following location:

```
/usr/share/doc/kernel-doc-<kernel_version>/Documentation/<arch>/mtrr.txt
```

E.2.23. /proc/partitions

This file contains partition block allocation information. A sampling of this file from a basic system looks similar to the following:

```
major minor  #blocks  name
  3     0   19531250 hda
  3     1     104391 hda1
  3     2   19422585 hda2
253     0   22708224 dm-0
253     1     524288 dm-1
```

Most of the information here is of little importance to the user, except for the following columns:

- **major** — The major number of the device with this partition. The major number in the **/proc/partitions**, (**3**), corresponds with the block device **ide0**, in **/proc/devices**.
- **minor** — The minor number of the device with this partition. This serves to separate the partitions into different physical devices and relates to the number at the end of the name of the partition.
- **#blocks** — Lists the number of physical disk blocks contained in a particular partition.
- **name** — The name of the partition.

E.2.24. /proc/slabinfo

This file gives full information about memory usage on the *slab* level. Linux kernels greater than version 2.2 use *slab pools* to manage memory above the page level. Commonly used objects have their own slab pools.

Instead of parsing the highly verbose **/proc/slabinfo** file manually, the **/usr/bin/slabtop** program displays kernel slab cache information in real time. This program allows for custom configurations, including column sorting and screen refreshing.

A sample screen shot of **/usr/bin/slabtop** usually looks like the following example:

```
Active / Total Objects (% used)    : 133629 / 147300 (90.7%)
Active / Total Slabs (% used)      : 11492 / 11493 (100.0%)
Active / Total Caches (% used)     : 77 / 121 (63.6%)
Active / Total Size (% used)       : 41739.83K / 44081.89K (94.7%)
Minimum / Average / Maximum Object : 0.01K / 0.30K / 128.00K
OBJS   ACTIVE USE      OBJ   SIZE     SLABS OBJ/SLAB CACHE SIZE NAME
44814  43159  96%    0.62K   7469      6     29876K ext3_inode_cache
36900  34614  93%    0.05K    492     75      1968K buffer_head
35213  33124  94%    0.16K   1531     23      6124K dentry_cache
```

```
7364   6463  87%    0.27K    526      14      2104K radix_tree_node
2585   1781  68%    0.08K     55      47       220K vm_area_struct
2263   2116  93%    0.12K     73      31       292K size-128
1904   1125  59%    0.03K     16      119        64K size-32
1666    768  46%    0.03K     14      119        56K anon_vma
1512   1482  98%    0.44K    168       9       672K inode_cache
1464   1040  71%    0.06K     24      61        96K size-64
1320    820  62%    0.19K     66      20       264K filp
678    587  86%    0.02K      3      226        12K dm_io
678    587  86%    0.02K      3      226        12K dm_tio
576    574  99%    0.47K     72       8       288K proc_inode_cache
528    514  97%    0.50K     66       8       264K size-512
492    372  75%    0.09K     12      41        48K bio
465    314  67%    0.25K     31      15       124K size-256
452    331  73%    0.02K      2      226         8K biovec-1
420    420 100%    0.19K     21      20        84K skbuff_head_cache
305    256  83%    0.06K      5      61        20K biovec-4
290      4   1%    0.01K      1      290         4K revoke_table
264    264 100%    4.00K    264       1      1056K size-4096
260    256  98%    0.19K     13      20        52K biovec-16
260    256  98%    0.75K     52       5       208K biovec-64
```

Some of the more commonly used statistics in **/proc/slabinfo** that are included into **/usr/bin/slabtop** include:

- **OBJS** — The total number of objects (memory blocks), including those in use (allocated), and some spares not in use.
- **ACTIVE** — The number of objects (memory blocks) that are in use (allocated).
- **USE** — Percentage of total objects that are active. ((ACTIVE/OBJS)(100))
- **OBJ SIZE** — The size of the objects.
- **SLABS** — The total number of slabs.
- **OBJ/SLAB** — The number of objects that fit into a slab.
- **CACHE SIZE** — The cache size of the slab.
- **NAME** — The name of the slab.

For more information on the **/usr/bin/slabtop** program, refer to the **slabtop** man page.

E.2.25. /proc/stat

This file keeps track of a variety of different statistics about the system since it was last restarted. The contents of **/proc/stat**, which can be quite long, usually begins like the following example:

```
cpu  259246 7001 60190 34250993 137517 772 0
cpu0 259246 7001 60190 34250993 137517 772 0
intr 354133732 347209999 2272 0 4 4 0 0 3 1 1249247 0 0 80143 0 422626 5169433
ctxt 12547729
btime 1093631447
processes 130523
procs_running 1
procs_blocked 0
preempt 5651840
cpu  209841 1554 21720 118519346 72939 154 27168
cpu0 42536 798 4841 14790880 14778 124 3117
```

```
cpu1 24184 569 3875 14794524 30209 29 3130
cpu2 28616 11 2182 14818198 4020 1 3493
cpu3 35350 6 2942 14811519 3045 0 3659
cpu4 18209 135 2263 14820076 12465 0 3373
cpu5 20795 35 1866 14825701 4508 0 3615
cpu6 21607 0 2201 14827053 2325 0 3334
cpu7 18544 0 1550 14831395 1589 0 3447
intr 15239682 14857833 6 0 6 6 0 5 0 1 0 0 0 29 0 2 0 0 0 0 0 0 0 94982 0 286812
ctxt 4209609
btime 1078711415
processes 21905
procs_running 1
procs_blocked 0
```

Some of the more commonly used statistics include:

- **cpu** — Measures the number of *jiffies* (1/100 of a second for x86 systems) that the system has been in user mode, user mode with low priority (nice), system mode, idle task, I/O wait, IRQ (hardirq), and softirq respectively. The IRQ (hardirq) is the direct response to a hardware event. The IRQ takes minimal work for queuing the "heavy" work up for the softirq to execute. The softirq runs at a lower priority than the IRQ and therefore may be interrupted more frequently. The total for all CPUs is given at the top, while each individual CPU is listed below with its own statistics. The following example is a 4-way Intel Pentium Xeon configuration with multi-threading enabled, therefore showing four physical processors and four virtual processors totaling eight processors.
- **page** — The number of memory pages the system has written in and out to disk.
- **swap** — The number of swap pages the system has brought in and out.
- **intr** — The number of interrupts the system has experienced.
- **btime** — The boot time, measured in the number of seconds since January 1, 1970, otherwise known as the *epoch*.

E.2.26. /proc/swaps

This file measures swap space and its utilization. For a system with only one swap partition, the output of **/proc/swaps** may look similar to the following:

```
Filename                        Type        Size    Used    Priority
/dev/mapper/VolGroup00-LogVol01 partition   524280  0       -1
```

While some of this information can be found in other files in the **/proc/** directory, **/proc/swap** provides a snapshot of every swap file name, the type of swap space, the total size, and the amount of space in use (in kilobytes). The priority column is useful when multiple swap files are in use. The lower the priority, the more likely the swap file is to be used.

E.2.27. /proc/sysrq-trigger

Using the **echo** command to write to this file, a remote root user can execute most System Request Key commands remotely as if at the local terminal. To **echo** values to this file, the **/proc/sys/kernel/sysrq** must be set to a value other than **0**. For more information about the System Request Key, refer to *Section E.3.9.3, " /proc/sys/kernel/ "*.

Although it is possible to write to this file, it cannot be read, even by the root user.

E.2.28. /proc/uptime

This file contains information detailing how long the system has been on since its last restart. The output of **/proc/uptime** is quite minimal:

```
350735.47 234388.90
```

The first number is the total number of seconds the system has been up. The second number is how much of that time the machine has spent idle, in seconds.

E.2.29. /proc/version

This file specifies the version of the Linux kernel, the version of **gcc** used to compile the kernel, and the time of kernel compilation. It also contains the kernel compiler's user name (in parentheses).

```
Linux version 2.6.8-1.523 (user@foo.redhat.com) (gcc version 3.4.1 20040714 \  (Red Hat
 Enterprise Linux 3.4.1-7)) #1 Mon Aug 16 13:27:03 EDT 2004
```

This information is used for a variety of purposes, including the version data presented when a user logs in.

E.3. Directories within /proc/

Common groups of information concerning the kernel are grouped into directories and subdirectories within the **/proc/** directory.

E.3.1. Process Directories

Every **/proc/** directory contains a number of directories with numerical names. A listing of them may be similar to the following:

```
dr-xr-xr-x    3 root     root            0 Feb 13 01:28 1
dr-xr-xr-x    3 root     root            0 Feb 13 01:28 1010
dr-xr-xr-x    3 xfs      xfs             0 Feb 13 01:28 1087
dr-xr-xr-x    3 daemon   daemon          0 Feb 13 01:28 1123
dr-xr-xr-x    3 root     root            0 Feb 13 01:28 11307
dr-xr-xr-x    3 apache   apache          0 Feb 13 01:28 13660
dr-xr-xr-x    3 rpc      rpc             0 Feb 13 01:28 637
dr-xr-xr-x    3 rpcuser  rpcuser         0 Feb 13 01:28 666
```

These directories are called *process directories*, as they are named after a program's process ID and contain information specific to that process. The owner and group of each process directory is set to the user running the process. When the process is terminated, its **/proc/** process directory vanishes.

Each process directory contains the following files:

- **cmdline** — Contains the command issued when starting the process.
- **cwd** — A symbolic link to the current working directory for the process.

- **environ** — A list of the environment variables for the process. The environment variable is given in all upper-case characters, and the value is in lower-case characters.
- **exe** — A symbolic link to the executable of this process.
- **fd** — A directory containing all of the file descriptors for a particular process. These are given in numbered links:

```
total 0
lrwx------    1 root     root           64 May  8 11:31 0 -> /dev/null
lrwx------    1 root     root           64 May  8 11:31 1 -> /dev/null
lrwx------    1 root     root           64 May  8 11:31 2 -> /dev/null
lrwx------    1 root     root           64 May  8 11:31 3 -> /dev/ptmx
lrwx------    1 root     root           64 May  8 11:31 4 -> socket:[7774817]
lrwx------    1 root     root           64 May  8 11:31 5 -> /dev/ptmx
lrwx------    1 root     root           64 May  8 11:31 6 -> socket:[7774829]
lrwx------    1 root     root           64 May  8 11:31 7 -> /dev/ptmx
```

- **maps** — A list of memory maps to the various executables and library files associated with this process. This file can be rather long, depending upon the complexity of the process, but sample output from the **sshd** process begins like the following:

```
08048000-08086000 r-xp 00000000 03:03 391479     /usr/sbin/sshd
08086000-08088000 rw-p 0003e000 03:03 391479 /usr/sbin/sshd
08088000-08095000 rwxp 00000000 00:00 0
40000000-40013000 r-xp 0000000 03:03 293205 /lib/ld-2.2.5.so
40013000-40014000 rw-p 00013000 03:03 293205 /lib/ld-2.2.5.so
40031000-40038000 r-xp 00000000 03:03 293282 /lib/libpam.so.0.75
40038000-40039000 rw-p 00006000 03:03 293282 /lib/libpam.so.0.75
40039000-4003a000 rw-p 00000000 00:00 0
4003a000-4003c000 r-xp 00000000 03:03 293218 /lib/libdl-2.2.5.so
4003c000-4003d000 rw-p 00001000 03:03 293218 /lib/libdl-2.2.5.so
```

- **mem** — The memory held by the process. This file cannot be read by the user.
- **root** — A link to the root directory of the process.
- **stat** — The status of the process.
- **statm** — The status of the memory in use by the process. Below is a sample **/proc/statm** file:

```
263 210 210 5 0 205 0
```

The seven columns relate to different memory statistics for the process. From left to right, they report the following aspects of the memory used:

1. Total program size, in kilobytes.
2. Size of memory portions, in kilobytes.
3. Number of pages that are shared.
4. Number of pages that are code.
5. Number of pages of data/stack.

6. Number of library pages.

7. Number of dirty pages.

- **`status`** — The status of the process in a more readable form than **`stat`** or **`statm`**. Sample output for **`sshd`** looks similar to the following:

```
Name: sshd
State: S (sleeping)
Tgid: 797
Pid: 797
PPid: 1
TracerPid: 0
Uid: 0 0 0 0
Gid: 0 0 0 0
FDSize: 32
Groups:
VmSize:     3072 kB
VmLck:         0 kB
VmRSS:      840 kB
VmData:      104 kB
VmStk:       12 kB
VmExe:      300 kB
VmLib:     2528 kB
SigPnd: 0000000000000000
SigBlk: 0000000000000000
SigIgn: 8000000000001000
SigCgt: 0000000000014005
CapInh: 0000000000000000
CapPrm: 00000000ffffffeff
CapEff: 00000000ffffffeff
```

  The information in this output includes the process name and ID, the state (such as **`S (sleeping)`** or **`R (running)`**), user/group ID running the process, and detailed data regarding memory usage.

E.3.1.1. /proc/self/

The **`/proc/self/`** directory is a link to the currently running process. This allows a process to look at itself without having to know its process ID.

Within a shell environment, a listing of the **`/proc/self/`** directory produces the same contents as listing the process directory for that process.

E.3.2. /proc/bus/

This directory contains information specific to the various buses available on the system. For example, on a standard system containing PCI and USB buses, current data on each of these buses is available within a subdirectory within **`/proc/bus/`** by the same name, such as **`/proc/bus/pci/`**.

The subdirectories and files available within **`/proc/bus/`** vary depending on the devices connected to the system. However, each bus type has at least one directory. Within these bus directories are normally at least one subdirectory with a numerical name, such as **`001`**, which contain binary files.

For example, the **`/proc/bus/usb/`** subdirectory contains files that track the various devices on any USB buses, as well as the drivers required for them. The following is a sample listing of a **`/proc/bus/usb/`** directory:

```
total 0 dr-xr-xr-x    1 root     root            0 May  3 16:25 001
-r--r--r--    1 root     root            0 May  3 16:25 devices
-r--r--r--    1 root     root            0 May  3 16:25 drivers
```

The **/proc/bus/usb/001/** directory contains all devices on the first USB bus and the **devices** file identifies the USB root hub on the motherboard.

The following is a example of a **/proc/bus/usb/devices** file:

```
T:  Bus=01 Lev=00 Prnt=00 Port=00 Cnt=00 Dev#=  1 Spd=12  MxCh= 2
B:  Alloc=  0/900 us ( 0%), #Int=  0, #Iso=  0
D:  Ver= 1.00 Cls=09(hub  ) Sub=00 Prot=00 MxPS= 8 #Cfgs=  1
P:  Vendor=0000 ProdID=0000 Rev= 0.00
S:  Product=USB UHCI Root Hub
S:  SerialNumber=d400
C:* #Ifs= 1 Cfg#= 1 Atr=40 MxPwr=  0mA
I:  If#= 0 Alt= 0 #EPs= 1 Cls=09(hub  ) Sub=00 Prot=00 Driver=hub
E:  Ad=81(I) Atr=03(Int.) MxPS=   8 Ivl=255ms
```

E.3.3. /proc/bus/pci

Later versions of the 2.6 Linux kernel have obsoleted the **/proc/pci** directory in favor of the **/proc/bus/pci** directory. Although you can get a list of all PCI devices present on the system using the command **cat /proc/bus/pci/devices**, the output is difficult to read and interpret.

For a human-readable list of PCI devices, run the following command:

```
~]# /sbin/lspci -vb
00:00.0 Host bridge: Intel Corporation 82X38/X48 Express DRAM Controller
        Subsystem: Hewlett-Packard Company Device 1308
        Flags: bus master, fast devsel, latency 0
        Capabilities: [e0] Vendor Specific Information <?>
        Kernel driver in use: x38_edac
        Kernel modules: x38_edac

00:01.0 PCI bridge: Intel Corporation 82X38/X48 Express Host-Primary PCI Express Bridge
 (prog-if 00 [Normal decode])
        Flags: bus master, fast devsel, latency 0
        Bus: primary=00, secondary=01, subordinate=01, sec-latency=0
        I/O behind bridge: 00001000-00001fff
        Memory behind bridge: f0000000-f2ffffff
        Capabilities: [88] Subsystem: Hewlett-Packard Company Device 1308
        Capabilities: [80] Power Management version 3
        Capabilities: [90] MSI: Enable+ Count=1/1 Maskable- 64bit-
        Capabilities: [a0] Express Root Port (Slot+), MSI 00
        Capabilities: [100] Virtual Channel <?>
        Capabilities: [140] Root Complex Link <?>
        Kernel driver in use: pcieport
        Kernel modules: shpchp

00:1a.0 USB Controller: Intel Corporation 82801I (ICH9 Family) USB UHCI Controller #4 (rev
 02) (prog-if 00 [UHCI])
        Subsystem: Hewlett-Packard Company Device 1308
        Flags: bus master, medium devsel, latency 0, IRQ 5
        I/O ports at 2100
        Capabilities: [50] PCI Advanced Features
        Kernel driver in use: uhci_hcd
[output truncated]
```

The output is a sorted list of all IRQ numbers and addresses as seen by the cards on the PCI bus instead of as seen by the kernel. Beyond providing the name and version of the device, this list also gives detailed IRQ information so an administrator can quickly look for conflicts.

E.3.4. /proc/driver/

This directory contains information for specific drivers in use by the kernel.

A common file found here is **rtc** which provides output from the driver for the system's *Real Time Clock (RTC)*, the device that keeps the time while the system is switched off. Sample output from **/proc/driver/rtc** looks like the following:

```
rtc_time        : 16:21:00
rtc_date        : 2004-08-31
rtc_epoch       : 1900
alarm           : 21:16:27
DST_enable      : no
BCD             : yes
24hr            : yes
square_wave     : no
alarm_IRQ       : no
update_IRQ      : no
periodic_IRQ    : no
periodic_freq   : 1024
batt_status     : okay
```

For more information about the RTC, refer to the following installed documentation:

/usr/share/doc/kernel-doc-<*kernel_version*>/Documentation/rtc.txt.

E.3.5. /proc/fs

This directory shows which file systems are exported. If running an NFS server, typing **cat /proc/fs/nfsd/exports** displays the file systems being shared and the permissions granted for those file systems. For more on file system sharing with NFS, refer to the *Network File System (NFS)* chapter of the *Storage Administration Guide*.

E.3.6. /proc/irq/

This directory is used to set IRQ to CPU affinity, which allows the system to connect a particular IRQ to only one CPU. Alternatively, it can exclude a CPU from handling any IRQs.

Each IRQ has its own directory, allowing for the individual configuration of each IRQ. The **/proc/irq/prof_cpu_mask** file is a bitmask that contains the default values for the **smp_affinity** file in the IRQ directory. The values in **smp_affinity** specify which CPUs handle that particular IRQ.

For more information about the **/proc/irq/** directory, refer to the following installed documentation:

```
/usr/share/doc/kernel-doc-kernel_version/Documentation/filesystems/proc.txt
```

E.3.7. /proc/net/

This directory provides a comprehensive look at various networking parameters and statistics. Each directory and virtual file within this directory describes aspects of the system's network configuration. Below is a partial list of the **/proc/net/** directory:

- **arp** — Lists the kernel's ARP table. This file is particularly useful for connecting a hardware address to an IP address on a system.
- **atm/** directory — The files within this directory contain *Asynchronous Transfer Mode (ATM)* settings and statistics. This directory is primarily used with ATM networking and ADSL cards.
- **dev** — Lists the various network devices configured on the system, complete with transmit and receive statistics. This file displays the number of bytes each interface has sent and received, the number of packets inbound and outbound, the number of errors seen, the number of packets dropped, and more.
- **dev_mcast** — Lists Layer2 multicast groups on which each device is listening.
- **igmp** — Lists the IP multicast addresses which this system joined.
- **ip_conntrack** — Lists tracked network connections for machines that are forwarding IP connections.
- **ip_tables_names** — Lists the types of **iptables** in use. This file is only present if **iptables** is active on the system and contains one or more of the following values: **filter**, **mangle**, or **nat**.
- **ip_mr_cache** — Lists the multicast routing cache.
- **ip_mr_vif** — Lists multicast virtual interfaces.
- **netstat** — Contains a broad yet detailed collection of networking statistics, including TCP timeouts, SYN cookies sent and received, and much more.
- **psched** — Lists global packet scheduler parameters.
- **raw** — Lists raw device statistics.
- **route** — Lists the kernel's routing table.
- **rt_cache** — Contains the current routing cache.
- **snmp** — List of Simple Network Management Protocol (SNMP) data for various networking protocols in use.
- **sockstat** — Provides socket statistics.
- **tcp** — Contains detailed TCP socket information.
- **tr_rif** — Lists the token ring RIF routing table.
- **udp** — Contains detailed UDP socket information.
- **unix** — Lists UNIX domain sockets currently in use.
- **wireless** — Lists wireless interface data.

E.3.8. /proc/scsi/

The primary file in this directory is **/proc/scsi/scsi**, which contains a list of every recognized SCSI device. From this listing, the type of device, as well as the model name, vendor, SCSI channel and ID data is available.

For example, if a system contains a SCSI CD-ROM, a tape drive, a hard drive, and a RAID controller, this file looks similar to the following:

```
Attached devices:
Host: scsi1
Channel: 00
Id: 05
Lun: 00
Vendor: NEC
Model: CD-ROM DRIVE:466
Rev: 1.06
Type:   CD-ROM
ANSI SCSI revision: 02
Host: scsi1
Channel: 00
Id: 06
Lun: 00
Vendor: ARCHIVE
Model: Python 04106-XXX
Rev: 7350
Type:   Sequential-Access
ANSI SCSI revision: 02
Host: scsi2
Channel: 00
Id: 06
Lun: 00
Vendor: DELL
Model: 1x6 U2W SCSI BP
Rev: 5.35
Type:   Processor
ANSI SCSI revision: 02
Host: scsi2
Channel: 02
Id: 00
Lun: 00
Vendor: MegaRAID
Model: LD0 RAID5 34556R
Rev: 1.01
Type:   Direct-Access
ANSI SCSI revision: 02
```

Each SCSI driver used by the system has its own directory within **/proc/scsi/**, which contains files specific to each SCSI controller using that driver. From the previous example, **aic7xxx/** and **megaraid/** directories are present, since two drivers are in use. The files in each of the directories typically contain an I/O address range, IRQ information, and statistics for the SCSI controller using that driver. Each controller can report a different type and amount of information. The Adaptec AIC-7880 Ultra SCSI host adapter's file in this example system produces the following output:

```
Adaptec AIC7xxx driver version: 5.1.20/3.2.4
Compile Options:
TCQ Enabled By Default : Disabled
AIC7XXX_PROC_STATS     : Enabled
AIC7XXX_RESET_DELAY    : 5
Adapter Configuration:
SCSI Adapter: Adaptec AIC-7880 Ultra SCSI host adapter
Ultra Narrow Controller     PCI MMAPed
I/O Base: 0xfcffe000
```

```
Adapter SEEPROM Config: SEEPROM found and used.
Adaptec SCSI BIOS: Enabled
IRQ: 30
SCBs: Active 0, Max Active 1, Allocated 15, HW 16, Page 255
Interrupts: 33726
BIOS Control Word: 0x18a6
Adapter Control Word: 0x1c5f
Extended Translation: Enabled
Disconnect Enable Flags: 0x00ff
Ultra Enable Flags: 0x0020
Tag Queue Enable Flags: 0x0000
Ordered Queue Tag Flags: 0x0000
Default Tag Queue Depth: 8
Tagged Queue By Device array for aic7xxx
host instance 1:       {255,255,255,255,255,255,255,255,255,255,255,255,255,255,255,255}
Actual queue depth per device for aic7xxx host instance 1:
 {1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1}
Statistics:

(scsi1:0:5:0) Device using Narrow/Sync transfers at 20.0 MByte/sec, offset 15
Transinfo settings: current(12/15/0/0), goal(12/15/0/0), user(12/15/0/0)
Total transfers 0 (0 reads and 0 writes)
  < 2K      2K+     4K+     8K+    16K+    32K+    64K+   128K+
Reads:         0       0       0       0       0       0       0       0
Writes:        0       0       0       0       0       0       0       0

(scsi1:0:6:0) Device using Narrow/Sync transfers at 10.0 MByte/sec, offset 15
Transinfo settings: current(25/15/0/0), goal(12/15/0/0), user(12/15/0/0)
Total transfers 132 (0 reads and 132 writes)
  < 2K      2K+     4K+     8K+    16K+    32K+    64K+   128K+
Reads:         0       0       0       0       0       0       0       0
Writes:        0       0       0       1     131       0       0       0
```

This output reveals the transfer speed to the SCSI devices connected to the controller based on channel ID, as well as detailed statistics concerning the amount and sizes of files read or written by that device. For example, this controller is communicating with the CD-ROM at 20 megabytes per second, while the tape drive is only communicating at 10 megabytes per second.

E.3.9. /proc/sys/

The **/proc/sys/** directory is different from others in **/proc/** because it not only provides information about the system but also allows the system administrator to immediately enable and disable kernel features.



Be careful when changing the content of /proc/sys/

Use caution when changing settings on a production system using the various files in the **/proc/sys/** directory. Changing the wrong setting may render the kernel unstable, requiring a system reboot.

For this reason, be sure the options are valid for that file before attempting to change any value in **/proc/sys/**.

A good way to determine if a particular file can be configured, or if it is only designed to provide information, is to list it with the **-l** option at the shell prompt. If the file is writable, it may be used to configure the kernel. For example, a partial listing of **/proc/sys/fs** looks like the following:

```
-r--r--r--    1 root     root            0 May 10 16:14 dentry-state
-rw-r--r--    1 root     root            0 May 10 16:14 dir-notify-enable
-rw-r--r--    1 root     root            0 May 10 16:14 file-max
-r--r--r--    1 root     root            0 May 10 16:14 file-nr
```

In this listing, the files **dir-notify-enable** and **file-max** can be written to and, therefore, can be used to configure the kernel. The other files only provide feedback on current settings.

Changing a value within a **/proc/sys/** file is done by echoing the new value into the file. For example, to enable the System Request Key on a running kernel, type the command:

```
echo 1 > /proc/sys/kernel/sysrq
```

This changes the value for **sysrq** from **0** (off) to **1** (on).

A few **/proc/sys/** configuration files contain more than one value. To correctly send new values to them, place a space character between each value passed with the **echo** command, such as is done in this example:

```
echo 4 2 45 > /proc/sys/kernel/acct
```



Changes made using the echo command are not persistent

Any configuration changes made using the **echo** command disappear when the system is restarted. To make configuration changes take effect after the system is rebooted, refer to *Section E.4, "Using the sysctl Command"*.

The **/proc/sys/** directory contains several subdirectories controlling different aspects of a running kernel.

E.3.9.1. /proc/sys/dev/

This directory provides parameters for particular devices on the system. Most systems have at least two directories, **cdrom/** and **raid/**. Customized kernels can have other directories, such as **parport/**, which provides the ability to share one parallel port between multiple device drivers.

The **cdrom/** directory contains a file called **info**, which reveals a number of important CD-ROM parameters:

```
CD-ROM information, Id: cdrom.c 3.20 2003/12/17
drive name:             hdc
drive speed:            48
drive # of slots:       1
Can close tray:         1
Can open tray:          1
Can lock tray:          1
Can change speed:       1
Can select disk:        0
Can read multisession:  1
```

```
Can read MCN:           1
Reports media changed:  1
Can play audio:         1
Can write CD-R:         0
Can write CD-RW:        0
Can read DVD:           0
Can write DVD-R:        0
Can write DVD-RAM:      0
Can read MRW:           0
Can write MRW:          0
Can write RAM:          0
```

This file can be quickly scanned to discover the qualities of an unknown CD-ROM. If multiple CD-ROMs are available on a system, each device is given its own column of information.

Various files in **/proc/sys/dev/cdrom**, such as **autoclose** and **checkmedia**, can be used to control the system's CD-ROM. Use the **echo** command to enable or disable these features.

If RAID support is compiled into the kernel, a **/proc/sys/dev/raid/** directory becomes available with at least two files in it: **speed_limit_min** and **speed_limit_max**. These settings determine the acceleration of RAID devices for I/O intensive tasks, such as resyncing the disks.

E.3.9.2. /proc/sys/fs/

This directory contains an array of options and information concerning various aspects of the file system, including quota, file handle, inode, and dentry information.

The **binfmt_misc/** directory is used to provide kernel support for miscellaneous binary formats.

The important files in **/proc/sys/fs/** include:

- **dentry-state** — Provides the status of the directory cache. The file looks similar to the following:

  ```
  57411 52939 45 0 0 0
  ```

  The first number reveals the total number of directory cache entries, while the second number displays the number of unused entries. The third number tells the number of seconds between when a directory has been freed and when it can be reclaimed, and the fourth measures the pages currently requested by the system. The last two numbers are not used and display only zeros.

- **file-max** — Lists the maximum number of file handles that the kernel allocates. Raising the value in this file can resolve errors caused by a lack of available file handles.

- **file-nr** — Lists the number of allocated file handles, used file handles, and the maximum number of file handles.

- **overflowgid** and **overflowuid** — Defines the fixed group ID and user ID, respectively, for use with file systems that only support 16-bit group and user IDs.

E.3.9.3. /proc/sys/kernel/

This directory contains a variety of different configuration files that directly affect the operation of the kernel. Some of the most important files include:

- **acct** — Controls the suspension of process accounting based on the percentage of free space available on the file system containing the log. By default, the file looks like the following:

```
4 2 30
```

The first value dictates the percentage of free space required for logging to resume, while the second value sets the threshold percentage of free space when logging is suspended. The third value sets the interval, in seconds, that the kernel polls the file system to see if logging should be suspended or resumed.

- **ctrl-alt-del** — Controls whether **Ctrl**+**Alt**+**Delete** gracefully restarts the computer using **init** (**0**) or forces an immediate reboot without syncing the dirty buffers to disk (**1**).
- **domainname** — Configures the system domain name, such as **example.com**.
- **exec-shield** — Configures the Exec Shield feature of the kernel. Exec Shield provides protection against certain types of buffer overflow attacks.

  There are two possible values for this virtual file:

  - **0** — Disables Exec Shield.
  - **1** — Enables Exec Shield. This is the default value.



Using Exec Shield

If a system is running security-sensitive applications that were started while Exec Shield was disabled, these applications must be restarted when Exec Shield is enabled in order for Exec Shield to take effect.

- **hostname** — Configures the system hostname, such as **www.example.com**.
- **hotplug** — Configures the utility to be used when a configuration change is detected by the system. This is primarily used with USB and Cardbus PCI. The default value of **/sbin/hotplug** should not be changed unless testing a new program to fulfill this role.
- **modprobe** — Sets the location of the program used to load kernel modules. The default value is **/sbin/modprobe** which means **kmod** calls it to load the module when a kernel thread calls **kmod**.
- **msgmax** — Sets the maximum size of any message sent from one process to another and is set to **8192** bytes by default. Be careful when raising this value, as queued messages between processes are stored in non-swappable kernel memory. Any increase in **msgmax** would increase RAM requirements for the system.
- **msgmnb** — Sets the maximum number of bytes in a single message queue. The default is **16384**.
- **msgmni** — Sets the maximum number of message queue identifiers. The default is **4008**.
- **osrelease** — Lists the Linux kernel release number. This file can only be altered by changing the kernel source and recompiling.
- **ostype** — Displays the type of operating system. By default, this file is set to **Linux**, and this value can only be changed by changing the kernel source and recompiling.

- **overflowgid** and **overflowuid** — Defines the fixed group ID and user ID, respectively, for use with system calls on architectures that only support 16-bit group and user IDs.
- **panic** — Defines the number of seconds the kernel postpones rebooting when the system experiences a kernel panic. By default, the value is set to **0**, which disables automatic rebooting after a panic.
- **printk** — This file controls a variety of settings related to printing or logging error messages. Each error message reported by the kernel has a *loglevel* associated with it that defines the importance of the message. The loglevel values break down in this order:
  - **0** — Kernel emergency. The system is unusable.
  - **1** — Kernel alert. Action must be taken immediately.
  - **2** — Condition of the kernel is considered critical.
  - **3** — General kernel error condition.
  - **4** — General kernel warning condition.
  - **5** — Kernel notice of a normal but significant condition.
  - **6** — Kernel informational message.
  - **7** — Kernel debug-level messages.

  Four values are found in the **printk** file:

  ```
  6     4     1     7
  ```

  Each of these values defines a different rule for dealing with error messages. The first value, called the *console loglevel*, defines the lowest priority of messages printed to the console. (Note that, the lower the priority, the higher the loglevel number.) The second value sets the default loglevel for messages without an explicit loglevel attached to them. The third value sets the lowest possible loglevel configuration for the console loglevel. The last value sets the default value for the console loglevel.
- **random/** directory — Lists a number of values related to generating random numbers for the kernel.
- **sem** — Configures *semaphore* settings within the kernel. A semaphore is a System V IPC object that is used to control utilization of a particular process.
- **shmall** — Sets the total amount of shared memory that can be used at one time on the system, in bytes. By default, this value is **2097152**.
- **shmmax** — Sets the largest shared memory segment size allowed by the kernel. By default, this value is **33554432**. However, the kernel supports much larger values than this.
- **shmmni** — Sets the maximum number of shared memory segments for the whole system. By default, this value is **4096**.
- **sysrq** — Activates the System Request Key, if this value is set to anything other than zero (**0**), the default.

The System Request Key allows immediate input to the kernel through simple key combinations. For example, the System Request Key can be used to immediately shut down or restart a system, sync all mounted file systems, or dump important information to the console. To initiate a System Request Key, type **Alt**+**SysRq**+ ***system request code*** . Replace *system request code* with one of the following system request codes:

- **r** — Disables raw mode for the keyboard and sets it to XLATE (a limited keyboard mode which does not recognize modifiers such as **Alt**, **Ctrl**, or **Shift** for all keys).
- **k** — Kills all processes active in a virtual console. Also called *Secure Access Key* (*SAK*), it is often used to verify that the login prompt is spawned from **init** and not a trojan copy designed to capture usernames and passwords.
- **b** — Reboots the kernel without first unmounting file systems or syncing disks attached to the system.
- **c** — Crashes the system without first unmounting file systems or syncing disks attached to the system.
- **o** — Shuts off the system.
- **s** — Attempts to sync disks attached to the system.
- **u** — Attempts to unmount and remount all file systems as read-only.
- **p** — Outputs all flags and registers to the console.
- **t** — Outputs a list of processes to the console.
- **m** — Outputs memory statistics to the console.
- **0** through **9** — Sets the log level for the console.
- **e** — Kills all processes except **init** using SIGTERM.
- **i** — Kills all processes except **init** using SIGKILL.
- **l** — Kills all processes using SIGKILL (including **init**). *The system is unusable after issuing this System Request Key code.*
- **h** — Displays help text.

This feature is most beneficial when using a development kernel or when experiencing system freezes.



Be careful when enabling the System Request Key feature

The System Request Key feature is considered a security risk because an unattended console provides an attacker with access to the system. For this reason, it is turned off by default.

Refer to **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/sysrq.txt** for more information about the System Request Key.

- **tainted** — Indicates whether a non-GPL module is loaded.

- **0** — No non-GPL modules are loaded.
- **1** — At least one module without a GPL license (including modules with no license) is loaded.
- **2** — At least one module was force-loaded with the command **insmod -f**.

- **threads-max** — Sets the maximum number of threads to be used by the kernel, with a default value of **2048**.
- **version** — Displays the date and time the kernel was last compiled. The first field in this file, such as **#3**, relates to the number of times a kernel was built from the source base.

E.3.9.4. /proc/sys/net/

This directory contains subdirectories concerning various networking topics. Various configurations at the time of kernel compilation make different directories available here, such as **ethernet/**, **ipv4/**, **ipx/**, and **ipv6/**. By altering the files within these directories, system administrators are able to adjust the network configuration on a running system.

Given the wide variety of possible networking options available with Linux, only the most common **/proc/sys/net/** directories are discussed.

The **/proc/sys/net/core/** directory contains a variety of settings that control the interaction between the kernel and networking layers. The most important of these files are:

- **message_burst** — Sets the amount of time in tenths of a second required to write a new warning message. This setting is used to mitigate *Denial of Service* (*DoS*) attacks. The default setting is **10**.
- **message_cost** — Sets a cost on every warning message. The higher the value of this file (default of **5**), the more likely the warning message is ignored. This setting is used to mitigate DoS attacks.

  The idea of a DoS attack is to bombard the targeted system with requests that generate errors and fill up disk partitions with log files or require all of the system's resources to handle the error logging. The settings in **message_burst** and **message_cost** are designed to be modified based on the system's acceptable risk versus the need for comprehensive logging.
- **netdev_max_backlog** — Sets the maximum number of packets allowed to queue when a particular interface receives packets faster than the kernel can process them. The default value for this file is **1000**.
- **optmem_max** — Configures the maximum ancillary buffer size allowed per socket.
- **rmem_default** — Sets the receive socket buffer default size in bytes.
- **rmem_max** — Sets the receive socket buffer maximum size in bytes.
- **wmem_default** — Sets the send socket buffer default size in bytes.
- **wmem_max** — Sets the send socket buffer maximum size in bytes.

The **/proc/sys/net/ipv4/** directory contains additional networking settings. Many of these settings, used in conjunction with one another, are useful in preventing attacks on the system or when using the system to act as a router.



Be careful when changing these files

An erroneous change to these files may affect remote connectivity to the system.

The following is a list of some of the more important files within the **/proc/sys/net/ipv4/** directory:

- **icmp_echo_ignore_all** and **icmp_echo_ignore_broadcasts** — Allows the kernel to ignore ICMP ECHO packets from every host or only those originating from broadcast and multicast addresses, respectively. A value of **0** allows the kernel to respond, while a value of **1** ignores the packets.
- **ip_default_ttl** — Sets the default *Time To Live (TTL)*, which limits the number of hops a packet may make before reaching its destination. Increasing this value can diminish system performance.
- **ip_forward** — Permits interfaces on the system to forward packets to one other. By default, this file is set to **0**. Setting this file to **1** enables network packet forwarding.
- **ip_local_port_range** — Specifies the range of ports to be used by TCP or UDP when a local port is needed. The first number is the lowest port to be used and the second number specifies the highest port. Any systems that expect to require more ports than the default 1024 to 4999 should use a range from 32768 to 61000.
- **tcp_syn_retries** — Provides a limit on the number of times the system re-transmits a SYN packet when attempting to make a connection.
- **tcp_retries1** — Sets the number of permitted re-transmissions attempting to answer an incoming connection. Default of **3**.
- **tcp_retries2** — Sets the number of permitted re-transmissions of TCP packets. Default of **15**.

The file called

```
/usr/share/doc/kernel-doc-kernel_version/Documentation/networking/ip-sysctl.txt
```

contains a complete list of files and options available in the **/proc/sys/net/ipv4/** directory.

A number of other directories exist within the **/proc/sys/net/ipv4/** directory and each covers a different aspect of the network stack. The **/proc/sys/net/ipv4/conf/** directory allows each system interface to be configured in different ways, including the use of default settings for unconfigured devices (in the **/proc/sys/net/ipv4/conf/default/** subdirectory) and settings that override all special configurations (in the **/proc/sys/net/ipv4/conf/all/** subdirectory).

The **/proc/sys/net/ipv4/neigh/** directory contains settings for communicating with a host directly connected to the system (called a network neighbor) and also contains different settings for systems more than one hop away.

Routing over IPV4 also has its own directory, **/proc/sys/net/ipv4/route/**. Unlike **conf/** and **neigh/**, the **/proc/sys/net/ipv4/route/** directory contains specifications that apply to routing with any interfaces on the system. Many of these settings, such as **max_size**, **max_delay**, and **min_delay**, relate to controlling the size of the routing cache. To clear the routing cache, write any value to the **flush** file.

Additional information about these directories and the possible values for their configuration files can be found in:

```
/usr/share/doc/kernel-doc-kernel_version/Documentation/filesystems/proc.txt
```

E.3.9.5. /proc/sys/vm/

This directory facilitates the configuration of the Linux kernel's virtual memory (VM) subsystem. The kernel makes extensive and intelligent use of virtual memory, which is commonly referred to as swap space.

The following files are commonly found in the **/proc/sys/vm/** directory:

- **block_dump** — Configures block I/O debugging when enabled. All read/write and block dirtying operations done to files are logged accordingly. This can be useful if diagnosing disk spin up and spin downs for laptop battery conservation. All output when **block_dump** is enabled can be retrieved via **dmesg**. The default value is **0**.

  Stopping the klogd daemon

  If **block_dump** is enabled at the same time as kernel debugging, it is prudent to stop the **klogd** daemon, as it generates erroneous disk activity caused by **block_dump**.

- **dirty_background_ratio** — Starts background writeback of dirty data at this percentage of total memory, via a pdflush daemon. The default value is **10**.

- **dirty_expire_centisecs** — Defines when dirty in-memory data is old enough to be eligible for writeout. Data which has been dirty in-memory for longer than this interval is written out next time a pdflush daemon wakes up. The default value is **3000**, expressed in hundredths of a second.

- **dirty_ratio** — Starts active writeback of dirty data at this percentage of total memory for the generator of dirty data, via pdflush. The default value is **20**.

- **dirty_writeback_centisecs** — Defines the interval between pdflush daemon wakeups, which periodically writes dirty in-memory data out to disk. The default value is **500**, expressed in hundredths of a second.

- **laptop_mode** — Minimizes the number of times that a hard disk needs to spin up by keeping the disk spun down for as long as possible, therefore conserving battery power on laptops. This increases efficiency by combining all future I/O processes together, reducing the frequency of spin ups. The default value is **0**, but is automatically enabled in case a battery on a laptop is used.

  This value is controlled automatically by the acpid daemon once a user is notified battery power is enabled. No user modifications or interactions are necessary if the laptop supports the ACPI (Advanced Configuration and Power Interface) specification.

  For more information, refer to the following installed documentation:

  /usr/share/doc/kernel-doc-*kernel_version*/Documentation/laptop-mode.txt

- **max_map_count** — Configures the maximum number of memory map areas a process may have. In most cases, the default value of **65536** is appropriate.
- **min_free_kbytes** — Forces the Linux VM (virtual memory manager) to keep a minimum number of kilobytes free. The VM uses this number to compute a **pages_min** value for each **lowmem** zone in the system. The default value is in respect to the total memory on the machine.
- **nr_hugepages** — Indicates the current number of configured **hugetlb** pages in the kernel.

  For more information, refer to the following installed documentation:

  /usr/share/doc/kernel-doc-*kernel_version*/Documentation/vm/hugetlbpage.txt
- **nr_pdflush_threads** — Indicates the number of pdflush daemons that are currently running. This file is read-only, and should not be changed by the user. Under heavy I/O loads, the default value of two is increased by the kernel.
- **overcommit_memory** — Configures the conditions under which a large memory request is accepted or denied. The following three modes are available:
  - **0** — The kernel performs heuristic memory over commit handling by estimating the amount of memory available and failing requests that are blatantly invalid. Unfortunately, since memory is allocated using a heuristic rather than a precise algorithm, this setting can sometimes allow available memory on the system to be overloaded. This is the default setting.
  - **1** — The kernel performs no memory over commit handling. Under this setting, the potential for memory overload is increased, but so is performance for memory intensive tasks (such as those executed by some scientific software).
  - **2** — The kernel fails requests for memory that add up to all of swap plus the percent of physical RAM specified in **/proc/sys/vm/overcommit_ratio**. This setting is best for those who desire less risk of memory overcommitment.

    Using this setting

    This setting is only recommended for systems with swap areas larger than physical memory.
- **overcommit_ratio** — Specifies the percentage of physical RAM considered when **/proc/sys/vm/overcommit_memory** is set to **2**. The default value is **50**.
- **page-cluster** — Sets the number of pages read in a single attempt. The default value of **3**, which actually relates to 16 pages, is appropriate for most systems.
- **swappiness** — Determines how much a machine should swap. The higher the value, the more swapping occurs. The default value, as a percentage, is set to **60**.

All kernel-based documentation can be found in the following locally installed location:

/usr/share/doc/kernel-doc-*kernel_version*/Documentation/, which contains additional information.

E.3.10. /proc/sysvipc/

This directory contains information about System V IPC resources. The files in this directory relate to System V IPC calls for messages (**msg**), semaphores (**sem**), and shared memory (**shm**).

E.3.11. /proc/tty/

This directory contains information about the available and currently used *tty devices* on the system. Originally called *teletype devices*, any character-based data terminals are called tty devices.

In Linux, there are three different kinds of tty devices. *Serial devices* are used with serial connections, such as over a modem or using a serial cable. *Virtual terminals* create the common console connection, such as the virtual consoles available when pressing **Alt+<F-key>** at the system console. *Pseudo terminals* create a two-way communication that is used by some higher level applications, such as XFree86. The **drivers** file is a list of the current tty devices in use, as in the following example:

```
serial               /dev/cua        5  64-127 serial:callout
serial               /dev/ttyS       4  64-127 serial
pty_slave            /dev/pts      136   0-255 pty:slave
pty_master           /dev/ptm      128   0-255 pty:master
pty_slave            /dev/ttyp       3   0-255 pty:slave
pty_master           /dev/pty        2   0-255 pty:master
/dev/vc/0            /dev/vc/0       4       0 system:vtmaster
/dev/ptmx            /dev/ptmx       5       2 system
/dev/console         /dev/console    5       1 system:console
/dev/tty             /dev/tty        5       0 system:/dev/tty
unknown              /dev/vc/%d      4    1-63 console
```

The **/proc/tty/driver/serial** file lists the usage statistics and status of each of the serial tty lines.

In order for tty devices to be used as network devices, the Linux kernel enforces *line discipline* on the device. This allows the driver to place a specific type of header with every block of data transmitted over the device, making it possible for the remote end of the connection to a block of data as just one in a stream of data blocks. SLIP and PPP are common line disciplines, and each are commonly used to connect systems to one other over a serial link.

E.3.12. /proc/*PID*/

Out of Memory (OOM) refers to a computing state where all available memory, including swap space, has been allocated. When this situation occurs, it will cause the system to panic and stop functioning as expected. There is a switch that controls OOM behavior in **/proc/sys/vm/panic_on_oom**. When set to **1** the kernel will panic on OOM. A setting of **0** instructs the kernel to call a function named **oom_killer** on an OOM. Usually, **oom_killer** can kill rogue processes and the system will survive.

The easiest way to change this is to echo the new value to **/proc/sys/vm/panic_on_oom**.

```
# cat /proc/sys/vm/panic_on_oom
1

# echo 0 > /proc/sys/vm/panic_on_oom

# cat /proc/sys/vm/panic_on_oom
```

```
0
```

It is also possible to prioritize which processes get killed by adjusting the **oom_killer** score. In **/proc/*PID*/** there are two tools labeled **oom_adj** and **oom_score**. Valid scores for **oom_adj** are in the range -16 to +15. To see the current **oom_killer** score, view the **oom_score** for the process. **oom_killer** will kill processes with the highest scores first.

This example adjusts the oom_score of a process with a *PID* of 12465 to make it less likely that **oom_killer** will kill it.

```
# cat /proc/12465/oom_score
79872

# echo -5 > /proc/12465/oom_adj

# cat /proc/12465/oom_score
78
```

There is also a special value of -17, which disables **oom_killer** for that process. In the example below, **oom_score** returns a value of 0, indicating that this process would not be killed.

```
# cat /proc/12465/oom_score
78

# echo -17 > /proc/12465/oom_adj

# cat /proc/12465/oom_score
0
```

A function called **badness()** is used to determine the actual score for each process. This is done by adding up 'points' for each examined process. The process scoring is done in the following way:

1. The basis of each process's score is its memory size.
2. The memory size of any of the process's children (not including a kernel thread) is also added to the score
3. The process's score is increased for 'niced' processes and decreased for long running processes.
4. Processes with the **CAP_SYS_ADMIN** and **CAP_SYS_RAWIO** capabilities have their scores reduced.
5. The final score is then bitshifted by the value saved in the **oom_adj** file.

Thus, a process with the highest **oom_score** value will most probably be a non-priviliged, recently started process that, along with its children, uses a large amount of memory, has been 'niced', and handles no raw I/O.

E.4. Using the sysctl Command

The **/sbin/sysctl** command is used to view, set, and automate kernel settings in the **/proc/sys/** directory.

For a quick overview of all settings configurable in the **/proc/sys/** directory, type the **/sbin/sysctl -a** command as root. This creates a large, comprehensive list, a small portion of which looks something like the following:

```
net.ipv4.route.min_delay = 2 kernel.sysrq = 0 kernel.sem = 250     32000     32     128
```

This is the same information seen if each of the files were viewed individually. The only difference is the file location. For example, the **/proc/sys/net/ipv4/route/min_delay** file is listed as **net.ipv4.route.min_delay**, with the directory slashes replaced by dots and the **proc.sys** portion assumed.

The **sysctl** command can be used in place of **echo** to assign values to writable files in the **/proc/sys/** directory. For example, instead of using the command

```
echo 1 > /proc/sys/kernel/sysrq
```

use the equivalent **sysctl** command as follows:

```
sysctl -w kernel.sysrq="1"
kernel.sysrq = 1
```

While quickly setting single values like this in **/proc/sys/** is helpful during testing, this method does not work as well on a production system as special settings within **/proc/sys/** are lost when the machine is rebooted. To preserve custom settings, add them to the **/etc/sysctl.conf** file.

Each time the system boots, `systemd` executes **sysctl** using the **/etc/sysctl.conf** configuration file to determine the values passed to the kernel. Any values added to **/etc/sysctl.conf** therefore take effect each time the system boots.

Additionally, `systemd` determines the contents of several directories including **/etc/sysctl.d/** and reads values from any file with the **.conf** extension. The **/etc/sysctl.d/** directory can be used to organize values into different files, and also permits them to be disabled by changing the extension of the file. For a complete list of directories read by `systemd`, refer to the **sysctl.d**(5) manual page.

E.5. References

Below are additional sources of information about **proc** file system.

Installed Documentation

Some of the best documentation about the **proc** file system is installed on the system by default.

- **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/filesystems/proc.txt** — Contains assorted, but limited, information about all aspects of the **/proc/** directory.
- **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/sysrq.txt** — An overview of System Request Key options.
- **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/sysctl/** — A directory containing a variety of **sysctl** tips, including modifying values that concern the kernel (**kernel.txt**), accessing file systems (**fs.txt**), and virtual memory use (**vm.txt**).
- **/usr/share/doc/kernel-doc-*kernel_version*/Documentation/networking/ip-sysctl.txt** — A detailed overview of IP networking options.

Useful Websites

- *http://www.linuxhq.com/* — This website maintains a complete database of source, patches, and documentation for various versions of the Linux kernel.

Appendix F. Revision History

Revision 1-1 **Thu Aug 9 2012** **Jaromír Hradílek** *jhradilek@redhat.com*

Updated *Chapter 7, Network Interfaces*.

Revision 1-0 **Tue May 29 2012** **Jaromír Hradílek** *jhradilek@redhat.com*

Fedora 17 release of the *System Administrator's Guide*.

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